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A SYSTEM

OF

THEORETICAL AND PRACTICAL

CHEMISTRY.

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IN TWO VOLUMES, WITH PLATES.

BY FREDERIC ACCUM,

Operative Chemist, Lecturer on Practical Chemistry, and on Mineralogy and Pharmacy; Late Chemical Operator in the Royal Institution of Great Britain.

WITH AN APPENDIX,

CONTAINING

A VIEW OF THE LATE DOCTRINES AND DISCOVERIES

IN CHEMISTRY.

BY THOMAS COOPER, ESQUIRE,

Professor of Chemistry at Dickinson College, Carlisle, Pennsylvania.

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A SYSTEM

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PART XXXIII.

METALS.

AMONG the simple substances which present themselves to our view in examining the products of nature, there are none of which the study is more important than METALS. Their utility is highly interesting. In all the revolutions of the science, these bodies have afforded facts of the greatest importance. From their constant influence on the progress of reason, they occupy a distinct place in the annals of chemical philosophy; and thus there is no production in nature which deserves more profound attention, more constant study, or more exact description than metals. They may be considered as the great instruments of human industry. Many of the mechanic arts could not possibly exist without them; and it is even doubtful whether mankind would have acquired that degree of civilization which characterizes the present state of society, without the use of these substances.

ENUMERATION OF METALS.

We are at present acquainted with twenty-nine metals, essentially differing from each other, namely,

1. Platina
2. Gold
3. Silver
4. Copper
5. Iron
6. Lead
7. Tin
8. Zinc
9. Mercury
10. Tellurium
11. Antimony
12. Bismuth
13. Manganese
14. Nickel
15. Nickolinum
16. Cobalt
17. Uranium
18. Titanium
19. Columbium
20. Chrome
21. Molybdena
22. Tungsten
23. Arsenic
24. Tantalium
25. Cerium
26. Palladium
27. Rhodium
28. Iridium
29. Osmium

NATURAL HISTORY OF METALS.

All the metals are found in the bowels of the earth, though sometimes they are on the surface. They are met with in different combinations with other matters, such as sulphur, oxygen, and acids; particularly with the carbonic, muriatic, sulphuric, and phosphoric acids. They are also found combined with each other, and sometimes, though rarely, in a pure metallic state, distinguishable by the naked eye.

In their different states of combination they are said to be mineralized, and are called ORES. The ores of metals are, for the most part, found in nature in mountainous districts; and always in such form a continued chain. There are mountains which consist entirely of iron ore; but in general the metallic part of a mountain bears a very inconsiderable proportion to its bulk. Ores are also met with in the cavities or crevices of rocks, forming what are termed VEINS, which are more easily discovered in these situations than when they lie level in plains.

The metallic matter of ores is very generally incrusted and intermingled with some earthy substance different from the rock in which the vein is situated; which is termed its MATRIX. This, however, must not be confounded with the mineralizing substance with which the metal is combined, such as sulphur, &c.

The art of distinguishing ores, and the method of describing them with accuracy and precision, so that they

may be known from each other, is called MINERALOGY.

The processes to discover the metals contained in them, to extract them from the earth, and to obtain them separate from the different matters which are united with them, and which conceal their properties, form a branch of Chemistry called the DOCIMASTIC ART.

The art of extracting metals in the large way is called METALLURGY.

GENERAL PHYSICAL PROPERTIES OF METALS.

All metals are combustible bodies. They possess a certain brilliancy, in consequence of the complete reflection of the light that falls upon them, which is termed *metallic lustre.* They are the most dense and heavy substances in nature; the heaviest fossil, not metallic, having a specific gravity much below that of the lightest metal. They are the most opaque of all bodies. A stone of the greatest opacity, when divided into thin plates, has more or less transparency; whereas gold is the only metal which admits of being reduced to such a degree of thinness as to admit the smallest perceptible transmission of light. Gold leaf, which is about $\frac{1}{280000}$ part of an inch in thickness, transmits light of a lively green colour; but silver, copper, and all the rest of the metals, are perfectly opaque. Another property which belongs exclusively to metals (though they do not all possess it) is *malleability;* by which is meant a capacity of having their surface increased, either in length or breadth, without being liable to fracture. This capacity is not precisely the same in those metals which do possess it; for some, which admit of extension when struck with a hammer, cannot be drawn into wire, which is properly termed *ductility;* this property depends in some measure on another peculiar quality of metals, namely *tenacity;** by which is meant the power which a metallic wire of a given diameter has of resisting the action of a weight suspended from its extremity. All metals are fusible, though the degree of temperature at which this can be effected differs very much. Mercury is always fluid at the ordinary temperature of our atmosphere, while platina

* Vide Vol. I. p. 66, and Appendix Note 6 thereto.

can scarcely be melted by the most intense heat of our furnaces. Metals are perfectly opaque when in a state of fusion; and are crystallizable when suffered to cool slowly and undisturbed. The tetrahedron and the cube are their primitive figures, though they very often take the octahedral form. They can likewise be volatilized at very high temperatures. They are the best conductors of caloric and electricity. They are the best reflectors of caloric and light. Iron and Nickel are magnetic. It is not certain that any of the other metals are so. Their susceptibility of combination is very great: they unite with carbon, sulphur, and phosphorus. They do not combine with earths by fusion; but their oxids readily unite to acids, alcalies and earths. They decompose water and several acids. Some effect this at common temperatures: some require a red-heat, and others the interposition of another body. Water does not dissolve any of the metals, though it is a solvent of some of their oxyds. They are insoluble in ardent spirit, ether, or oils. They are all capable of combining with oxygen, though many of them require very high temperatures to effect this union, and others cannot be united to it but in an indirect manner. Most of the metals can be combined with each other; they then form alloys, many of which are of the greatest utility in the arts. Gay Lussac has lately ascertained, that the proportion of acid in metallic salts, is as the quantity of oxygen in the oxyd which is their base. *Memoires d'Arcueil*, tom. 2. p. 159.

PLATINA.

PART XXXIV.

SECT. I.

NATURAL HISTORY OF PLATINA.

HITHERTO no mine of platina has been discovered. It is found in nature only in a metallic state in small grains, combined with palladium, rhodium, iridium, osmium, iron, copper, &c. The largest mass of which we have heard is one of the size of a pigeon's egg, in the possession of the Royal Society of Bergara. It is found in the parishes of Novita and Citaria, north from Choco in Peru, and near Carthagena in South America. It was unknown in Europe before the year 1748. Don Antonio Ulloa then gave the first information concerning its existence in the narrative of his voyage with the French academicians to Peru.

For a thorough knowledge of this ore we are indebted to Dr. Wolaston and Mr. Tennant.*

PROPERTIES OF PLATINA.

Platina purified from all extraneous mixture is of a white colour, intermediate between that of silver and tin. It is the hardest of all metals. Its specific gravity being from 20.6 to 23 makes it by far the heaviest body known. It is hard, malleable, ductile, laminable like gold; but to what degree is not yet ascertained. We have seen platina drawn into a wire of a smaller diameter than the two thousandth part of an inch. It is the most infusible of all the metals. It cannot be melted (in a considerable quan-

* Dr. Lewis first described platina as a new metal with many of its properties in 1754. T.C.

tity at least) by the most violent heat of our furnaces,* but may be fused by the heat of a burning lens, the assistance of oxygen gas, and by the galvanic spark. When pure, its parts may be made to combine or weld, by hammering in a white heat; a property confined to this metal and iron. It suffers no alteration from the action of air; neither water, the earths, nor the salino-terrene substances have any power of action upon it. Potash acts upon it at a high temperature. It is not oxydated when exposed red-hot to the air, for a very long time. It may however be oxydated by the galvano-electric spark, and by the nitro-muriatic acid. This acid dissolves it, and assumes first a yellow and afterwards a deep orange colour. The solution tinges animal substances with a dark colour, and may be decomposed by alcalies, and by muriate and nitrate of ammonia, which have no effect on solutions of gold. No other acid exercises any action upon it. The oxyd of platina is a triple compound, consisting of ammonia, muriatic acid, platina and the rest of the metals which the alloy contains. Platina combines with phosphorus and sulphur with considerable facility. It unites with the greater number of the metals by fusion. Of these alloys, that with copper is the most valuable, as it is ductile, susceptible of a fine polish, and does not tarnish on exposure to air; the rest of them are very little known, it is therefore unnecessary to dwell on them particularly.

METHOD OF OBTAINING PLATINA.

The processes most commonly employed to obtain pure platina are as follow.

1. Take equal parts of platina in grains,† and crude tartar or acidulous tartrite of potash: put the mixture into a well luted crucible, and expose it for two hours to a violent heat. The platina fuses, but it becomes brittle, and whiter than platina is in common; then expose it to a very strong heat under a muffle, by which means all the arsenic combined with it will be disengaged, and the platina remain behind in a malleable state.

2. Platina may likewise be obtained pure, by decomposing the nitro-muriatic solution of common platina, by

* I have about three ounces of crude platina, agglutinated but not melted in a heat of 172° of Wedgewood. T. C.

† I suspect the words "white arsenic" are wanted here. T. C.

muriate of ammonia, heating the precipitate intensely, and stamping it when of a white heat into one mass: or, by assisting the fusion with a stream of oxygen gas.

3. Jannetty's process, which is considered as the best, and which is generally used for obtaining malleable platina, is as follows:

Triturate common platina with water, to wash off every contaminating matter that water can carry away. Mix the platina with about one-fifth part of arsenious acid and one-fifteenth part of potash; putting the whole in a proper crucible, in the following manner: Having well heated the crucible and the furnace receiving it, put in one-third of the mixture, apply to this a strong heat, and add one-third more: after a renewed application of heat, throw in the last portion. After a thorough fusion of the whole, cool and break the mass. Then fuse it a second time, and, if necessary, even a third time, till it ceases to be magnetic. Break it into small pieces, and melt those pieces in separate crucibles, and in portions of a pound and a half of the platina to each crucible, with an equal quantity of arsenious acid and half a pound of potash. After cooling the contents of the different crucibles in a horizontal position, in order to have them throughout of equal thickness, heat them under a muffle to volatilize the arsenious acid, and maintain them in this state, without increase of heat, for the space of six hours Heat them, next, in common oil, till the oil shall have evaporated to dryness. Then immerse them in nitric acid, boil them in water, heat them to redness in a crucible, and hammer them into a dense mass. They are now fit to be heated in a naked fire, and hammered into bars for the purposes of commerce.

Mr. Richter directs, in order to purify platina, and render it malleable, the following process: Dissolve platina of commerce in nitro-muriatic acid, and let fall into this solution potash, until a precipitate begins to appear; then add a solution of sulphate of potash, till the whole is precipitated. Wash the precipitate till the water that passes do not change its colour by adding to it prussiate of potash. Dry the precipitate, and mix with it 1.5 times its weight of soda freed from its water of crystallization; press it into a crucible, but not so as to fill it; heat it gradually, and raise the heat till it fuses.*

* (For other methods, see Appendix No. 31.)

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF PLATINA.

EXPERIMENT. I.

Platina is soluble in nitro-muriatic acid.

IF one part of platina and ten of nitro-muriatic acid be presented to each other, a violent action takes place, and the platina becomes dissolved. On evaporating the solution, very small crystals of muriate of platina are deposited.

REMARK....This is the only saline combination of this metal, of which the properties have been examined; it appears that the platina exists in the solution in two states of oxydation. On adding potash to it, a precipitate is formed which is a triple compound of the alcali, acid, and platina highly oxydated; it is sparingly soluble in water; and of a saline nature. When more potash is added, another precipitate is thrown down, which is the imperfect oxyd of platina.

Ammonia acts in a similar manner on the solution; and the muriate of ammonia likewise forms a triple compound of oxyd of platina, muriatic acid, and ammonia, which being insoluble is precipitated. *By this property of affording a precipitate on the addition of muriate of ammonia to its solution, platina is distinguished from every other metal.**

EXPERIMENT II.

Separation of platina from gold.

When gold is alloyed with platina, the adulteration cannot be discovered by hydrostatic examinations; but as muriate of ammonia has the property of precipitating platina, but not gold from the solution; and as fresh prepared sulphate of iron precipitates gold, but not platina; these salts furnish the means of separating the metals when added to the solution.

* Muriate of tin also throws down platina from its solutions, of a red colour. T.C.

Experiment III.

Platina combines with phosphorus.

(Phosphuret of Platina.)

Mix equal parts of platina and glacial acid of phosphorus with an eighth part of charcoal; put the whole into a crucible, and cover it with a little charcoal dust; expose it to a heat nearly equal to that which makes gold enter into fusion, and continue it for an hour; a button of a silver white colour will then be obtained, which exhibits in the inside crystals of a perfect cubical form; this is *phosphuret of platina.**

Experiment IV.

Phosphuret of Platina detonates with oxygenated muriate of potash.

If a mixture of phosphuret of platina and oxygenated muriate of potash be thrown into an ignited crucible, a strong detonation ensues, and the platina becomes separated in its metallic form. A similar effect is produced by throwing phosphuret of platina upon nitrate of potash.

Experiment V.

Platina is soluble in potash in the dry way.

If potash, prepared according to Berthollet's process, be kept in fusion for some time in a platina crucible, it will be found that this vessel has lost part of its weight, which is dissolved by the potash. For if we dissolve this alcali in water, and saturate the solution with muriatic acid, a triple salt will be obtained by evaporation, consisting of platina, muriatic acid, and potash. This fact was first noticed by Mr. Chenevix.†

* It combines also according to Davy (Elem. of Chem. Phil. 431) directly with phosphorus, with sulphur, and by galvanic process with oxygen. It has not yet been united to Hydrogen, Azot, or Carbon.....T. C.

† Philosoph. Trans. May 1802.

GOLD.

PART XXXV.

SECT. I.

NATURAL HISTORY OF GOLD.

GOLD is found in nature only in the metallic state, most commonly in grains, ramifications, leaves, or rhomboidal, octahedral, or pyramidical crystals. Its matrix is generally quartz, sand-stone, siliceous shistus, &c. It is found also in the sands of many rivers, particularly in Africa Hungary, and France,* in minute irregular grains, called *gold-dust*. Native gold found in compact masses, is never completely pure; it is alloyed with silver or copper, and sometimes with iron and tellurium. The largest piece of native gold that has been hitherto discovered in Europe was found in the county of Wicklow, in Ireland. Its weight was said to be 22 ounces, and the quantity of alloy it contained was very small. Several other pieces, exceeding one ounce, have also been discovered at the same place, in sand, covered with turf, and adjacent to a rivulet.

Gold is also met with in a particular sort of argentiferous copper pyrites, called in Hungary *Gelf*. This ore is found either massive, or crystallized in rhomboids, or other irregular quadrangular or polygonal masses. It exists likewise in the sulphurated ores of Nagaya, in Transylvania. These all contain the metal called tellurium. Berthollet and other French chemists have obtained gold out of the ashes of vegetables.

* Native Gold has, of late years, been found in Cabarrus county, North Carolina.....T. C.

PROPERTIES OF GOLD.

Gold is of a brilliant rich yellow colour; no other substance in nature is so heavy, platina excepted. Its specific gravity is 19.3. Its hardness is not very considerable. Its ductility is so considerable that a wire $\frac{1}{10}$ of an inch in diameter supports a weight of 500lb. without breaking.* It melts at 32° of Wedgwood's pyrometer, and when suffered to cool slowly crystallizes in short quadrangular pyramids. By an intense heat, as that of a [illegible] it is volatilized. It is incapable of oxydating at any temperature which our furnaces can yield. It is a good conductor of caloric, electricity, and galvanism. The two last [illegible] inflame it, and convert it into a purple oxyd, which is volatilized in the form of smoke. It does not unite with hydrogen, carbon, or with sulphur; though the latter when in the state of a sulphuret dissolves it. Phosphorus combines with it; arsenic, bismuth, and antimony form an antimate union with it. It easily alloys with mercury. With silver it forms an alloy of considerable ductility. Copper heightens its colour, and renders it harder without much impairing its ductility. Tin and lead greatly impair its tenacity. With platina it forms an alloy which is considerably ductile. Combined with zinc it affords a very brittle and hard mixture susceptible of a beautiful polish. It unites well with iron, and hardens it remarkably. Its ductility and malleability are far greater than any of the rest of the metals.

Remark....One grain of gold may easily be divided into two millions of parts; and a cubic inch of gold into nine thousand five hundred and twenty-three millions, eight hundred and nine thousand five hundred and twenty-three parts, each of which may be distinctly seen by the naked

Boyle, quoted by D'Apligny in his Treatise of Colours, says, that one grain and a half of gold may be beaten into 50 leaves of one inch square, which if intersected by parallel lines drawn at right angles to each other, and distant only the 100th part of an inch from each other, will produce 25 millions of little squares, each of which may be distinctly seen without the help of glasses.

* A wire .078 of an inch diameter, supports a weight of 150lb....Davy.

Mr. Magellan has informed us that its surface may be extended by the hammer 159,092 times, and that the finest gold leaf is that made in new skins, which must have an alloy of three grains of copper to the ounce troy of pure gold, or it would be too soft to pass over the irregularities of the skin.

He affirms, that 80 books, or 2000 leaves of gold, each measuring 3.3 square inches, viz. each containing 10.89 square inches, weigh less than 384 grains. Each book therefore, or 25 leaves = 272.23 inches weighs less than 4.8 grains; so that each grain of the metal will produce 56.718 square inches. From further calculations it may be made evident, that the thickness of these leaves is less than $\frac{1}{282,240}$th of an inch; and that sixteen ounces of gold, which, if in the form of a cube, would not measure more than one inch and one quarter on its side, will completely gild a silver wire sufficient in length to go round the whole earth like a hoop.

METHOD OF OBTAINING GOLD.

The processes for obtaining gold in the large way, from its different native combinations, or admixtures, vary, according to the state of the gold, and the nature of the substances which are found mixed with it.

When gold is in a state nearly pure (*native gold*) as it is found dispersed among stones, or mixed with sand, it may first be reduced to small granular pieces, together with the matrix: a table of several feet long, and one and a half broad, with ledges round three of its sides, and pieces of cloth with a long nap nailed on the board, is placed under a gentle stream of water, upon which the pounded ore or sand is thrown: by this contrivance, the lighter and heterogeneous substances are washed or carried off.

When the stuff or cloth is sufficiently charged with the particles of gold which adhere to it, on account of its superior gravity, it is disengaged from the board, and put into a vessel, where it is further agitated with water, and more freed from the lighter substances. It is then mixed with $\frac{1}{10}$ of mercury, and triturated in an iron or copper

vessel containing boiling water, until the mercury has absorbed all the gold particles. The mercury thus containing the gold in solution is to be separated first from the water, and next from the earthy particles, and then from the sand, by throwing the whole upon a table placed in an inclined direction; the mercury charged with gold, but still vivid, will, when assisted by a little stirring, or manipulation, run off the table, and leave the sand behind. The mercury is then separated from the gold (and silver if any) by exposing the alloy in earthen retorts to such a heat as will occasion the mercury to distil off, and is collected again in a receiver with water. The gold not being volatile in fire, is thus left behind, and is afterwards further freed from the heterogeneous imperfect metallic substances, by the process of cupellation.

After these processes, the silver, if the gold contains any, is separated by reducing it first to very fine laminæ, and then extracting the silver by nitric acid, which leaves the gold behind: the silver may be separated from the nitric acid, by muriatic acid, with which it forms muriate of silver. Muriate of silver is to be decomposed again, by mixing it with soda, and exposing it to a sufficient heat in a crucible, whereby the soda unites to the muriatic acid, and sets the silver free.

When gold is found mixed with sulphur or arsenic, and other metals, the ore must first be torrefied, which separates the greatest part of the arsenic and sulphur, and then melted with iron, which unites with what remains. The heterogeneous metallic substances are then separated by scorification with fluxes, consisting of tartrite of potash and nitrate of potash, which have no effect upon gold when the sulphur is previously separated: without this previous separation, the sulphur would unite with part of the alcali of the nitrate of potash, and form sulphuret of potash, which would take up a portion of the gold, and thus diminish the produce. The gold left by the melting with the flux is afterwards further purified by cupellation, or melting with lead.

When the gold ore is free from sulphur, it may, after being pounded and washed, be melted with one and a half part of semi-vitreous oxyd of lead,* and three parts of glass, in a crucible covered with muriate of soda. By this ope-

* Litharge.

ration, all the heterogeneous metals will scorify, and set the gold free.

SECT. II.

EXPERIMENTAL PROOF OF THE PROPERTIES OF GOLD.

EXPERIMENT I.

Gold is not acted on by any acid, the oxygenated muriatic and nitro-muriatic acid excepted.

INTRODUCE some gold-leaf in any acid, no solution will be effected by it; but if oxygenated muriatic acid, or nitro-muriatic acid, be made use of, a solution will be effected. If the gold-leaf be exposed to the action of the oxygenated muriatic acid in its gazeous state, it takes fire. See vol. i. p. 360.

A saturated solution of gold in these acids yields, by evaporation, crystals of muriate of gold, of a beautiful yellow colour, not unlike *topazes;* they consist sometimes of truncated octahedra, sometimes of tetrahedral prisms. When dissolved in water they tinge the skin indelibly of a deep purple colour, and produce the same effect upon almost all animal and vegetable bodies, and even upon marble.

RATIONALE....The gold robs the acid of part of its oxygen, and becomes oxydated; the oxygenated muriatic acid, or the nitro-muriatic acid, is converted into simple muriatic acid, in which state it is capable of dissolving the oxyd of gold, and constitutes with it *muriate of gold.*

REMARK....Though nitro-muriatic, or more properly oxygenated muriatic acid, is the only fluid capable of dissolving gold, it has been long ago noticed that nitrous acid, assisted by heat exercised some slight action on this metal, especially when in a state of extreme comminution.

EXPERIMENT II.

Gold is precipitated from its solution by tin.

(Preparation of the purple precipitate of Cassius.)

If we immerse into a solution of gold in nitro-muriatic acid a sheet of tin, the oxyd of gold is precipitated of a

purple colour, and, when scraped off and collected, forms the purple powder, or precipitate of Cassius, much employed in enamelling. It is a compound, consisting of oxyd of gold and oxyd of tin. It is best obtained for the purpose of enamelling by dissolving pure tin in diluted nitro-muriatic acid, composed of two parts of nitric and one of muriatic, acid, very slowly, and absolutely without heat, and then adding to this fresh-prepared solution, diluted with at least eighty times its weight of distilled water, a solution of pure gold in nitro-muriatic acid, collecting the precipitate, and washing it repeatedly with distilled water.

REMARK....It is absolutely necessary that the tin should be oxydated at its *minimum*, for the oxy-muriate of tin, which is already at a *Maximum* of oxydation, produces no such effect, because it cannot abstract oxygen from the oxyd of gold.

EXPERIMENT III.

Gold is precipitated from its solution by charcoal.

Into a perfectly neutral diluted solution of gold, contained in a glass jar, put a long narrow slip of well-burnt charcoal, and expose it to the direct rays of the sun; the gold will be revived and appear on the charcoal in a metallic state, exhibiting a very beautiful appearance. The same effect will be produced, without light, by boiling the charcoal in the solution for a few minutes.

EXPERIMENT IV.

Gold is precipitated by ether, essential oils, &c.

If highly-rectified ether, or an essential oil, be shaken together with a solution of gold, the gold will be precipitated; but it will be instantly dissolved by the ether or oil, and form with the first an *ethereal solution of gold*, which is of a golden yellow colour, and floats on the top of the fluid.

If the solution be evaporated the gold is obtained in a state of absolute purity.

REMARK....Gold thus dissolved was formerly called *potable gold*. It was anciently employed in medicine.

The apothecaries made their patients supply the gold, and pretended that the purer the gold, so much the speedier would be the cure. But these errors have been long exploded.

Experiment V.

Decomposition of muriate of gold by hydrogen, or sulphureous acid gas.

For these facts we are indebted to Mrs. Fulhame. She found, that if a white satin riband be moistened with a diluted solution of gold, in nitro-muriatic acid, and then exposed, while moist, to a current of hydrogen gas, the gold would be reduced, and the riband become gilt with the metal. But if the silk be dried previously, the reduction does not take place. By means of a camelhair pencil, the gold may be so applied as to exhibit regular ornaments, or figures, when reduced.

The same reduction takes place when the silk is dipped into phosphorated ether. If a piece of silk, moistened with phosphorated ether, be immersed in the nitro-muriatic solution, its surface is immediately gilt with a fine coat of gold, which adheres very strongly.

That phosphorated hydrogen gas produces the same effect has been noticed already. Sulphureous acid gas has a similar effect.

Remark....Mrs. Fulhame has proved* that the presence of moisture is absolutely necessary for the reduction of gold. It is difficult to ascertain what makes water so indispensably necessary. It is not, as might be supposed, requisite to secure the fluidity of the mixture; for she has ascertained that sulphuric ether, though a fluid, does not answer, except water be present. She accounts very ingeniously for the phenomena, by supposing the water to be decomposed. The combustible combines with its oxygen, while its hydrogen unites to the oxygen of the gold, and re-produces water. This theory accounts very well for the phenomena; but it would require some direct proofs to establish it completely.

* In her Essay on Combustion.

Experiment VI.

Decomposition of muriate of gold by ammonia.

(Preparation of fulminating gold.)

Dissolve pure gold in nitro-muriatic acid to saturation, and dilute the solution with three times its bulk of distilled water, and add to it gradually liquid ammonia, a yellow precipitate will be obtained, which must be repeatedly washed with distilled water, and dried on a chalk stone or in a filter. When perfectly dry it is called *fulminating gold*, and detonates by heat, as may be shown by heating a few grains of it on the point of a knife held over the candle. Its action is chiefly downwards.

Rationale....Though the theory of fulminating gold is not yet sufficiently illustrated, it appears highly probable that it is a triple compound; namely, an *ammoniacal oxymuriate of gold.* We suppose, therefore, that on the application of heat, the muriatic acid seizes the oxygen, and reduces the gold to its metallic state; while the acid itself becomes converted into oxygenized muriatic acid. We supppose farther, that after this change the acid detonates with the ammonia; in which case, part of its oxygen forms water with the hydrogen of the ammonia, and its nitrogen is set free. Hence the products of the detonation of fulminating gold seem to be metallic gold, nitrogen gas, and muriatic acid and water.

Experiment VII.

*Gold is precipitated by sulphate of iron.**

If we mingle a solution of gold with a diluted solution of green sulphate of iron, a precipitate instantly appears, which is gold in its metallic form, and in a state of purity.

Rationale....The green sulphated oxyd of iron seizes the oxygen of the gold, and hence the former re-appears in its metallic state.

Remark....The red sulphate of iron has no effect upon the solution of gold; the reason of this may be readily conceived from what has been stated before.

* Green: or recently prepared. T. G.

Experiment VIII.

A solution of gold stains animal and vegetable matters purplish red.

If a solution of gold be applied to bone, ivory, wood, feathers, linen, silk, &c. a stain will be left of a purplish-red colour, which cannot be effaced, on account of the strong attraction subsisting between the oxyd of gold and the substance to which it is applied. The traces are first purple, they afterwards become of a beautiful brown, and at last black. Hence a diluted solution of gold may be used for painting upon silk.

Experiment IX.

Gold may be separated from its combinations with other metals by sulphuret of antimony.

Put the alloy into a crucible with two parts of sulphuret of antimony, and when the mixture is in perfect fusion, take the crucible out of the fire and suffer it to cool; a sulphuret will be formed with the foreign metals at the upper part, and the gold will be found united to the antimony at the bottom of the crucible.

The gold may be separated from the antimony by bringing it to a white heat, by which means the antimony is volatilized.

Experiment X.

Gold when united to mercury is easily oxydated.

Put mercury with a forty-eighth part of its weight of gold into a flat-bottomed matrass, the neck of which must be drawn out into a capillary tube, and expose the mixture to heat in a sand-bath; the metals will become oxydated, and be converted into a dark coloured powder.

Experiment XI.

Gold unites with alcaline sulphurets both in the dry and humid way.

To exhibit this, some leaf-gold may be digested with heat in a solution of sulphuret of potash. Or,

Equal parts of sulphur and potash may be fused quickly with gold-leaf.

REMARK....Some chemists have persuaded themselves that this was the process made use of by Moses to render the Golden Calf, which the Israelites cast in that metal and set up in the wilderness, to worship during Moses's absence on the mount, potable, which, as related in Exod. XXXII. that legislator ground to powder, burnt, and mixt with the water the people were to drink. There is however nothing related concerning the operations necessary for that purpose.

GILDING,

Or the art of covering the surfaces of bodies with gold. Manufacturers use the term improperly to denote silvering, as well as gilding, and likewise the various methods of producing a golden colour without actually using gold.

The real application of gold, as a covering, may be performed, either by a metallic mixture after the manner of a pigment; or by friction, upon the same principle as black-lead and coloured chalks are used; or by the chemical precipitation of gold from mercury, or some other solvent; and, lastly, by glueing, or fastening gold leaves to the surface intended to be gilt.

Shell-gold, or gold powder

For painting, may be obtained by uniting one part of gold with eight of mercury, and afterwards evaporating the latter by heat, which leaves the gold in the form of powder; or otherwise the metal may be reduced to powder by mechanical trituration, as mentioned already under the article *shell-silver*.

Gold gilding by friction.

Steep a fine linen rag in a saturated solution of muriate of gold, till it has entirely imbibed the fluid; this rag must then be dried over a fire, and afterwards burnt to tinder. When any thing is to be gilt, it must be previously well burnished; a piece of cork is then to be dipped, first into

a solution of salt in water, and afterwards into the black powder ; and the piece, after being rubbed with it, must be burnished. This powder is frequently used for gilding delicate articles of silver.

Gilding of brass or copper.

Fine instruments of brass, in order that their surface may be kept longer clean, may be gilt by immersing them several times in a solution of muriate of gold, free from excess of acid, and afterwards burnishing them.

Water-gilding.

This term was probably at first confined to such processes as demand the use of a solation of gold in nitro-muriatic acid, and means a chemical application of gold to the surfaces of metals. If a solution of gold be copiously diluted with ardent spirits, a piece of polished steel will be gilt by being repeatedly steeped therein.

An improved process for gilding steel.

This method, which is less known among artists than it deserves to be, may prove useful to those who have occasion to gild steel.

The first part of the process consists in pouring into a solution of gold in nitro-muriatic acid, about twice as much sulphuric ether. In order to gild iron or steel, the metal must be highly polished. The ether which has taken up the gold is then to be applied with a small brush ; it evaporates, and the gold remains on the surface of the metal. In this manner all kind of figures may be delineated on steel, by employing a pen or fine brush. Lancets, razors, &c. may be gilt in this manner.

Gilding of iron, by means of heat,

Is performed by cleaning and polishing its surface, and then heating it till it has acquired a blue colour. When this has been done, the first layer of gold-leaf is put on, slightly burnished down, and exposed to a gentle fire. It is usual to give three such layers, or four at the most, each consisting of a single leaf, for common works ; or two for extraordinary ones. The heating is repeated at each layer, and last of all the work is burnished.

Grecian gilding

Is performed in the following manner: Equal parts of muriate of ammonia, and muriate of mercury, are dissolved in nitric acid, and a solution of gold is made in this fluid: upon this the solution is concentrated, and applied to the surface of silver, which becomes quite black; but on being exposed to a red heat, it assumes the appearance of gilding.

Method of gilding silver, brass, or copper, by means of an alloy of gold and mercury.

Eight parts of mercury and one of gold are alloyed together by heating them in a crucible. As soon as the gold is perfectly alloyed, the mixture is poured into cold water, and is then ready for use.

Before the alloy can be laid upon the surface of the metal, this last is brushed over with diluted nitric acid, in which it is of advantage that some mercury may have been dissolved. Some artists then wash the metal in simple water, and scour it a little with the finest sand, previous to the application of the gold; but others apply it to the metal while still wet with the nitric acid. But in either case, the alloy must be laid on as uniformly as possible, and spread very even with a brass-wire brush, wetted from time to time with water. The piece is then laid upon a grate over a charcoal fire, or in a small muffle or furnace, adapted to this purpose; the heat drives off the mercury, and leaves the gold behind. Its defects are then seen, and may be remedied by successive applications of more alloy, and additional application of heat. Expert artists however make these additional applications while the piece remains in the furnace, though the practice is said to be highly noxious, on account of the mercurial fumes. After this it is rubbed with gilders wax, which may consist of four ounces of bees wax, one ounce of acetite of copper, and one ounce of sulphate of copper; they then expose it to a red heat, which burns off the wax; and lastly, the work is cleansed with the scratch brush, and burnished, if necessary, with a steel tool. The use of the wax seems to consist merely in covering defects, by the diffusion of a quan-

tity of red oxyd of copper, which is left behind after the burning.

Painting with gold upon porcelain or glass,

Is done with the powder of gold which remains behind after driving off the muriatic acid from a solution of that metal, or by precipitating this solution by immersing plates of copper in it. It is laid on with super-saturated borate of soda, and gum-water, or oil, burned in and polished.

The gilding of glass

Is commonly effected by covering the part with a solution of super-saturated borate of soda, and applying gold-leaf upon it, which is afterwards fixed by burning.

The edges of tea cups, &c.

Are very frequently gilt in a less durable manner by applying a very thin coat of amber varnish, upon which gold-leaf is to be fixed, and when the varnish is dry, the gold is burnished.

The gilders of wood, and other compositions designed to supply the place of carved work, make use of gold-leaf, which is either laid on with size, or boiled oil, and afterwards burnished.

ANALYSIS OF ORES OF GOLD.

Native gold, when imbedded in earths, or stones, may be analysed by reducing the ore to a very fine powder, weighing a determinate portion, and effecting their solution in nitric or rather in nitro-muriatic acid, care being taken to digest the ore with the acid repeatedly, or as long as it extracts any thing. The solution must be evaporated to dryness, in order to free it as much as possible from its excess of acid, and then dissolved in water. If the ore contains silver, this metal will fall to the bottom in the form of a white heavy precipitate; it may be separated by filtration, and reduced by fusing it with soda. In order to

separate the gold, let the solution be made hot, and pour into it a solution of sulphate of iron, which precipitates the gold in its metallic state. The presence of copper in the ore may be detected by immersing a plate of iron in the solution, which will become coppered. Iron may be detected by tincture of galls, which occasions a blackish precipitate; and platina, by muriate of ammonia, which separates it. The minutest quantity of gold contained in an ore may be investigated, by letting fall into the solution a few drops of a solution of tin in muriatic acid, which instantly causes a purple precipitate.

When gold is found in sands, it can be obtained by simply washing the sand; for the lighter foreign substances will remain longer suspended, and carried off with the water, while the heavy particles of gold sink to the bottom with greater celerity.

PARTING, OR QUARTATION.

If gold be alloyed with silver, it is purified by a process sometimes called *parting*, and sometimes *quartation:* this last name is given on account of the proportion of materials employed: three parts of silver being added to the alloy, which of course makes a fourth part of the mixture. They are melted together, and sulphur thrown in: the sulphur combines with the silver, and the gold falls to the bottom. In the humid way gold is purified from silver by nitric acid, which rapidly dissolves silver, but has no action upon gold.

CUPELLATION.

If gold be alloyed with copper, lead, &c. it is purified by the process called *cupellation*, in the following manner: the alloyed gold is put with about twice its weight of silver, and some lead, into a crucible made of a very porous substance, such as bone-ashes, and called a *cupel.* They are all exposed to a considerable heat, which oxydates the lead, or converts it into a semi-vitreous oxyd of lead or litharge, enabling it likewise to form a similar kind of substance with the other metals in the alloy. This glassy fluid soaks into the pores of the cupel, while the remaining

mixture of gold and silver is left behind in the vessel: the silver is then separated from the gold as before stated.

It must be observed, that every alloy of gold is supposed to be divided into twenty-four parts, called *carats*, and that the purity of gold is estimated according to the number of those parts, which it makes up.

The gold coins of Great Britain are composed of 11 parts of gold, and one of copper; they are therefore gold of twenty-two carats.

Perfectly pure gold may be obtained by dissolving the gold of commerce in nitro-muriatic acid, and precipitating the metal by adding a weak solution of sulphate of iron. The precipitate after being well washed and dried is pure gold.

SILVER.

PART XXXVI.

SECT. I.

NATURAL HISTORY OF SILVER.

THIS metal is found both native and mineralized, and combined with lead, copper, mercury, cobalt, sulphur, arsenic, &c. The principal ores of this metal are the following: Native silver, antimoniated silver, sulphuret of silver, sulphurated oxyd of silver and antimony, muriate of silver, native oxyd of silver, &c. It is found in different parts of the earth. The mines of the Erzgeburge, and the metalliferous rocks of Mexico and Potosi, Bohemia, Norway, Transylvania, &c. are the richest.

Native silver possesses all the properties of this metal, and it appears in series of octahedra inserted in one another; in small capillary flexible threads intwined together; in plates; or in masses. The colour of native silver is white, often tarnished. Silver alloyed with gold forms the *auriferous native silver ore*. The colour of this ore is a yellowish white. It has much metallic lustre. The *antimoniated silver ore* belongs to this class. Silver combined with sulphur forms the *sulphurated oxyd of silver*, or *vitreous silver ore*. This ore occurs in masses, sometimes in threads, and sometimes crystallized in cubes or regular octahedra. Its colour is dark bluish gray, inclining to black. Its fracture is uneven, and its lustre metallic. It is soft enough to be cut with a knife. It is sometimes found alloyed with antimony (gray silver ore.) Silver united to muriatic acid forms the *corneous silver ore (muriate of silver)* which appears under different colours and shapes. Silver united to oxygen constitutes the *calciform silver ore*, of which there are several varieties. The colour of these

ores is a lead-gray, or grayish black. They occur massive, disseminated, and crystallized.

Germany, and other countries of Europe, but more especially Peru and Mexico in South America, contain the principal silver mines. There are, however, silver mines in Ireland, Norway, France, and many other parts of the world.

PROPERTIES OF SILVER.

Silver is very brilliant, white and sonorous. It is the most splendid of all the metals. Its specific gravity is from 10.474 to 11.091 according to the state of its density. It is exceedingly ductile and tenacious.* It may be beat out into leaves only $\frac{1}{100000}$ part of an inch thick, and drawn into wire the thousandth part of an inch thick. It melts at 28° of Wedgwood's pyrometer.† Exposed to a temperature considerably higher it becomes volatilized. Atmospheric air has no effect upon it except when it contains sulphureous vapours, sulphurated or phosphorated hydrogen gases. It unites to phosphorus and sulphur. It slightly unites with the brittle acidifiable metals; but it readily enters into combination with the greater number of the other metals. With gold it forms what is termed *green gold.* Copper renders it harder without much impairing its ductility. Mercury and silver combine and form a crystallizable and fusible alloy. It unites with the rest of the metals except cobalt and nickel. It is oxydated and dissolved by several of the acids. The nitric acid attacks it rapidly in the cold. The sulphuric acid requires a boiling heat. The muriatic acid does not act upon it. The acid solutions of silver are decomposable by alcalies, earths, and by the greater number of the metals.

METHOD OF OBTAINING SILVER.

Different methods are employed in different countries to extract silver from its ores. In Mexico, Peru, &c. the mineral is pounded, roasted, washed, and then triturated with mercury in vessels filled with water. A mill

* A wire of .078 of an inch will support 187$\frac{13}{100}$ lb. weight. DAVY.

† About 1000 of Fahrenheit. DAVY.

is employed to keep the whole in agitation. The silver combines by that means with the mercury. The alloy thus obtained is afterwards washed, to separate any foreign matters from it, and then strained and pressed through leather. This being done, heat is applied to drive off the mercury from the silver, which is then melted and cast into bars or ingots.

In order to extract silver from sulphurated or vitreous silver ore, the mineral is roasted, and then melted with lead and borax, or some other flux to assist the fusion. By the first operation the sulphur is volatilized, and by the second the silver is obtained, though for the most part alloyed with the other metals, from which it is separated by cupellation, or fusion with lead or bismuth.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF SILVER.

Experiment I.

Silver unites to phosphorus by fusion.

(Phosphuret of silver.)

MIX two parts of glacial acid of phosphorus and one of silver filings, with half a part of charcoal dust; introduce the mixture into a crucible, place it in a forge or furnace, and expose it to a red heat for about an hour.

When the fusion is complete, the silver appears at the bottom of the crucible in the middle of the fused glacial acid, and small jets of phosphorus project themselves from it; remove the crucible into the open air, and the metal will speedily cease to be fluid. The button obtained is *phosphuret of silver*, from which the phosphorus may be again separated by heat, leaving the silver pure.

Experiment II.

Silver unites to sulphur.

(Sulphuret of silver.)

Put plates of silver and sulphur reduced to powder into a crucible, in alternate strata, beginning with a stratum of

sulphur, and finishing with the silver; cover the crucible, place it among burning coals, and bring it to a red heat as expeditiously as possible. The two substances will thus combine, and the result is a mass of a dark violet colour, much more fusible than silver, brittle, and disposed in needles. This is *sulphuret of silver.*

Experiment III.

Silver enters into combination with sulphuret of potash in the dry way.

Fuse together, in a crucible, one part of silver and four of sulphuret of potash; stir the mixture frequently, and when it is well fused, pour it on a smooth stone, which has been rubbed with a little grease.

This compound is soluble in water, and the combination of the silver with the sulphuret is so intimate that it will pass through bibulous paper.

Experiment IV.

Silver unites to mercury with great facility.

Triturate in a marble mortar one part of silver-leaf and seven of mercury; the product will be an alloy which has but little consistence.

A similar combination may be effected by using silver filings; but in that case the trituration must be made in a warm mortar.

Remarks....This amalgam assumes a regular form by fusion and cooling slowly.

The mercury acquires a degree of fixity in this sort of combination; for it requires a much greater heat to separate it from the silver than is necessary to volatilize it alone.

Experiment V.

Silver decomposes sulphuric acid, at a boiling heat.

Put one part of silver filings into a retort, pour over it six of concentrated sulphuric acid, and heat the mixture over a lamp; the acid will be decomposed, the sulphu-

reous acid gas will be obtained. The residue in the retort is *sulphate of silver*, which by solution in a large quantity of boiling water, and evaporation, may be obtained in the form of small needle-shaped crystals.

Experiment VI.

Silver is dissolved by nitric acid, with great rapidity.

Pour nitric acid of a moderate strength upon some silver in a Florence flask; an effervescence will take place, the metal will be dissolved, and nitrous gas will be liberated copiously. If both the silver and acid are perfectly pure, the solution will be colourless; but if otherwise, it will have a milky or greenish hue.* If the solution be evaporated, it shoots into tabular or scaly crystals, called *nitrate of silver*.

Remark....A solution of nitrate of silver stains animal and vegetable substances of a deep black; and the colour produced is exceedingly permanent, hence it has been applied for the staining of human hair; but when thus made use of, it should be very much diluted, and used with great caution, on account of its corrosive property.

The article known by the name of *indelible, or permanent, marking ink* for marking linen, wearing apparel, &c. consists of a saturated solution of nitrate of silver, thickened with a little gum arabic.†

The fluid known by the name of *silver-test*, for detecting counterfeit silver coin, is a solution of standard silver considerably diluted.

Experiment VII.

Muriatic acid does not attack silver, but separates it from its solution.

Let fall some muriatic acid into a solution of nitrate of silver, a white curdy precipitate will be instantly formed in great abundance. This precipitate is decomposed by light; for if it be exposed to the direct rays of the sun, the white

* If the silver be alloyed with copper, the solution will be greenish. If the acid be contaminated with sulphuric or muriatic acids, the sulphate of silver, and the muriate of silver will fall down in white flakes. The sulphate may be separated from the muriate by boiling water. T. C.

† The cloth should be previously moistened with a weak solution of pearl ash, and then dried, &c. T. C.

colour will be changed to brown and afterwards to black. If fused by a gentle heat, it forms a semi-transparent mass of the consistency of horn; hence it was formerly called *horn-silver*, but now more properly *muriate of silver.*

REMARK....To reduce muriate of silver, let one part of it be mixt with three of soda freed from water, and expose it to a white heat. When the mixture is well fused, suffer it to cool; then break the crucible, and separate the silver from the muriate of soda which has been formed. The silver obtained by this means is exceedingly pure.

EXPERIMENT VIII.

Preparation of ammoniated oxyd of silver.

(Berthollet's fulminating silver.)

Dissolve fine silver in pale nitric acid, and precipitate the solution by lime water; decant the fluid; mix the precipitate with liquid ammonia, and stir it till it assumes a black colour; then decant the super-natant fluid, and leave it in the open air to dry. This product is fulminating silver, invented by Berthollet, which when once obtained *cannot be touched* without producing a violent explosion. It is the most dangerous preparation known, for the contact of fire is not necessary to cause it to detonate. It explodes by the mere touch of any substance. Its very preparation is so hazardous, that it is not to be safely attempted without a mask with strong glass eyes upon the face. No more than a single grain will admit of exhibiting its effect, and even that quantity must be approached with caution. A larger portion cannot be exploded without imminent danger.

RATIONALE.....The detonation of this compound is to be ascribed to the hydrogen of the ammonia suddenly combining with the oxygen of the metallic oxyd, and forming aqueous vapour, which is disengaged with the nitrogen gas; the elasticity of both the gases is augmented by the caloric which is disengaged. No explanation has yet been given why its force is so much greater than that of fulminating gold; but it is probably owing to the silver when in the state of an oxyd containing more oxygen than the gold, and to this oxyd combining with a larger portion of am-

monia; hence, in the sudden combination, more aqueous vapour and nitrogen gas will be disengaged.

REMARK....If the fluid which is separated from the precipitate be slowly evaporated, crystals are formed which explode more violently than the precipitate; a few grains of them cannot be touched without hazard of life.

EXPERIMENT IX.

Preparation of hyper-oxygenated muriate of silver.

(Chenevix's fulminating silver.)

Mr. Chenevix has lately invented a fulminating silver which is more safe than the former; for it explodes only by a slight friction in contact with combustible bodies. It may be prepared in the following manner:

Diffuse a quantity of alumine through water, and let a current of oxygenized muriatic acid gas pass through it for some time. Then digest some phosphate of silver (obtained by pouring a solution of phosphate of soda into a solution of nitrate of silver) on the solution of the oxygenated muriate of alumine, and evaporate it slowly. The product obtained will be a hyper-oxygenated muriate of silver; a single grain of which, in contact with two or three of sulphur, explodes violently by the slightest friction. (*See Appendix*, No. 32.)

EXPERIMENT X.

Arbor Dianæ.

Most metallic substances are capable of decomposing a nitric solution of silver. The separation of this metal by mercury, on account of the phenomena which it presents, has been called Diana's tree, or Arbor Dianæ.

According to Lemery, dissolve one part of fine silver in weak nitric acid to saturation, and, having diluted this solution with about twenty parts of distilled water, add two parts of mercury.

Homberg's method is to make an alloy in the cold, of four parts of silver-leaf and two parts of mercury; to dissolve this alloy in a sufficient quantity of nitric acid, and to add to the solution distilled water.

If we put into this liquor a small ball of soft alloy of silver, a precipitation of silver immediately takes place.

Baumé gives the following process, which will be attended with more success:

Mix together six parts of a solution of silver and four of a solution of mercury, both made with nitric acid, and completely saturated: add to them a little distilled water, and put the mixture into a conical vessel, into which have been previously introduced six parts of an alloy made of seven parts of mercury and one of silver.

At the end of some hours there will be formed, at the surface of the small mass of alloy, a vegetation in the form of a bush.

A process which succeeds better than any of the former, is to dissolve three drachms and 48 grains of pure silver and half as much mercury, separately, in a sufficient quantity of pure nitric acid. Mix the solutions, and add to them five or six ounces of distilled water. This must be poured upon seven drachms and 12 grains of an amalgam of silver of the consistence of butter, which had been previously put into a spherical vessel of glass. The vessel must be kept undisturbed, and in about 24 hours a very beautiful siver-tree will be formed.

RATIONALE....The mercury contained in the solution attracts that of the amalgam; the silver contained in the latter acts also on that which is held in solution; and the result of these attractions is a speedier precipitation of the silver. The mercury, which makes part of the amalgam, being more abundant than would be necessary for precipitating the silver of the solution, produces also a third effect, which is, that it attracts the silver by the affinity and tendency it has to combine itself with that metal.

REMARK....In order to obtain a beautiful vegetation, it is absolutely necessary that all the ingredients be of the utmost purity. A cylindrical or conical glass vessel is best suited for it.

EXPERIMENT XI.

Precipitation of silver by copper.

(Vegetation of silver on glass, slate, &c.)

Spread a few drops of a solution of silver in nitric acid, upon a smooth piece of slate, or on a plate of glass, by

means of a camel's-hair pencil or feather ; place at the bottom of it, in contact with the fluid, a copper or brass wire of about one sixteenth of an inch in diameter, and let the whole remain undisturbed in a horizontal position. Under a glass magnifier, or microscope, this vegetation appears in a beautiful manner.

RATIONALE....This phenomenon, like the former, is produced by the attraction of the copper, or brass; for nitric acid being stronger than that of the silver, the latter losing its oxygen, returns to the metallic state.

SILVERING.

There are various methods of giving a covering of silver to the surface of bodies. For instance,

Copper may be silvered over, by rubbing it with the following powder: Two drachms of acidulous tartrite of potash, the same quantity of muriate of soda, and half a drachm of sulphate of alumine, mixed with fifteen or twenty grains of silver, precipitated from nitrate of silver by copper. The surface of the copper becomes white when rubbed with this powder, which may afterwards be brushed off, and polished with leather.

The saddlers and harness-makers cover their wares with tin for ordinary uses (as stated before, page 135) but a cheap silvering is used for this purpose as follows: Half an ounce of silver that has been precipitated from nitrate of silver by the addition of copper ; muriate of soda, and muriate of ammonia, of each two ounces, and one drachm of muriate of mercury, are triturated together, and made into a paste with water; with this, copper utensils of every kind, that have been previously boiled with acidulous tartrite of potash, and sulphate of alumine, are rubbed, after which they are made red-hot, and then polished. The intention of this process appears to be little more than to apply the silver in a state of minute division to the clean surface of the copper, and afterwards to fix it there by fusion; and accordingly this silvering may be effected by using the argentine precipitate here mentioned with super-saturated borate of soda, or mercury, and causing it to adhere by fusion.

The dial plates of clocks, the scales of barometers, and other similar articles are silvered by rubbing upon them

a mixture of muriate of silver, muriate of soda, and acidulous tartrite of potash, and afterwards carefully washing off the saline matter with water. In this operation the silver is precipitated from the muriatic acid, which unites with part of the coppery surface. It is not durable, but may be improved by heating the article, and repeating the operation till the covering seems sufficiently thick.

Shell-silver for the use of painters is prepared by triturating silver-leaf with a little honey or mucilage of gum-arabic in a mortar, and afterwards separating the honey or gum by means of water. When the honey or gum is washed away, the silver may be put on paper or kept in shells, whence its name. When it is to be used, it must again be diluted with gum-water.

REMARK....The application of silver-leaf for silvering paper, wood, &c. is analogous to the application of gold-leaf.

PLATING.

The covering of the surface of copper with silver or plating is performed in the following manner: Upon small ingots of copper, plates of silver are bound with iron wire, generally allowing one ounce of silver to twelve ounces of copper. The surface of the plate of silver is not quite so large as that of the copper ingot. Upon the edges of the copper which are not covered by the silver, a little borax is put; and by exposing the whole to a strong heat, the borax melts, and in melting contributes to fuse that part of the silver to which it is contiguous, and to attach it in that state to the copper. The ingot, with its silver plate, is then rolled under steel rollers, moved by machinery, till it is of a certain thickness; it is afterwards cut to a greater or less extremity, according to the use for which it is intended.

An ounce of silver is often rolled out into a surface of about three square feet, and its thickness is about the three thousandth part of an inch; and hence we need not wonder at the silver being soon worn off from the sharp edges of plated copper, when it is rolled to so great an extent.

REMARK....What is commonly called French plate, is not to be confounded with plated copper. French plate is made by heating copper, or more commonly brass, to a

certain degree; silver-leaf is then applied upon the heated metal, to which it adheres by being rubbed with a proper burnisher.

ANALYSIS OF ORES OF SILVER.

The analysis of the ores of silver has been always considered as very important, on account of the great value of the metal which they contain.

The ore, called *native silver*, is to be dissolved in nitric acid. The gold, if the ore contains any, remains in the state of a black powder, and may be dried and weighed. The silver may then be precipitated, by adding to the solution common salt. Every hundred parts of the dried precipitate denote about 75 parts of silver. But, as lead may be present in the solution, and this metal is also precipitated by the muriatic acid of the common salt, it may be proper to immerse in the solution, which should not have an excess of acid, a polished plate of copper. This will precipitate the silver in a metallic form. The muriate of silver is soluble in liquid ammonia, but that of lead is not. The presence of copper may be ascertained by the green colour of the solution, and by the blue colour which it assumes on adding to it ammonia. The copper may be precipitated by immersing into it a plate of iron. When the ore contains arsenic, its proportion may be estimated by weighing before and after fusion; for the arsenic is dissipated by heat: or the ore may be dissolved as before in nitric acid, which acidifies the arsenic. After the separation of the silver, the arsenic acid may be precipitated by nitrate of lead, 100 parts of the dry precipitate indicating about 22 of arsenic.

Sulphuret of silver is to be treated with diluted nitric acid, which dissolves the silver, leaving the greater part of the sulphur untouched. The residuum is to be dried, and then the sulphur burnt off. The loss of weight gives the sulphur. The silver is to be precipitated by common salt; and the other metals, if any be present, may be ascertained as above. Part of the sulphur is always acidified. The acid thus formed may be precipitated by nitrate of barytes, 100 parts of the dried precipitate indicating about 14.5 of sulphur.

Antimoniated silver ore was analysed by Klaproth in the following manner: 100 parts of it were boiled in diluted nitric acid. The residuum, washed and dried, was 26. These 26 were digested in nitro-muriatic acid. The residuum now weighed 13 (so that 13 had been dissolved) 12 of which were sulphur, and burnt away, leaving behind one part of silex. The nitro-muriatic solution, when diluted largely with water, let fall a precipitate which weighed 13 (or 10 of pure antimony) and had the properties of oxyd of antimony; for they did not evaporate till heated to redness, but at that temperature were dissipated in a gray smoke.

The nitric solution was green. Common salt occasioned a precipitate which weighed 87.75, equivalent to 65.81 of pure silver. After the separation of this muriate of silver, sulphate of soda occasioned no precipitate. Therefore the solution contained no lead. When super-saturated with soda, a gray precipitate fell down, weighing 5 parts. On burning coals this precipitate gave out an arsenical smell. It was re-dissolved in nitric acid: sulphuret of potash occasioned a smutty brown precipitate; and Prussic alcali afforded Prussian blue, which, after torrefaction, was magnetic. Hence he concluded, that these 5 parts were a combination of iron and arsenic acid.*

Red silver ore was analysed by Vauquelin in the following manner: One hundred parts of it were digested in 500 parts of nitric acid previously diluted with water.† The undissolved residuum, being washed and dried, weighed 42.06. Being treated with muriatic acid, it was all dissolved except 14.66 parts, which were sulphur. The muriatic solution, when diluted with a great quantity of water, deposited a white powder, which weighed 21.25, and was oxyd of antimony. The nitric solution remained still to be examined. Muriatic acid occasioned a heavy precipitate, which was muriate of silver. Re-agents showed that the acid retained no other substance in solution.‡

Muriate of silver was analysed by Klaproth in the following manner: One hundred parts of it were mixed with thrice their weight of carbonate of potash, and melt-

* Klaproth's Beitrage, i. 163.

† No effervescence occurred during the solution; a proof that the metals existed in the ore in the state of oxyds.

‡ Jour. de Min. No. xvii. p. 2.

ed together in a glass retort. The mass was dissolved in water, and the solution filtered. A residuum remained, which was dissolved in nitric acid, with the exception of a red powder; which treated with nitro-muriatic acid, was dissolved, except a little muriate of silver, which, when reduced, yielded .5 of pure silver. Ammonia precipitated from the nitro-muriatic solution 2.5 parts of oxyd of iron. The nitric solution was precipitated with common salt; the muriate of silver, thus obtained, yielded, when reduced, 67.25 of silver.

The original aqueous solution of the alcaline mass was saturated with acetous acid, on which it deposited 1.75 parts of alumine. The solution was evaporated to dryness, and the dry mass treated with alcohol, which dissolved the acetite of potash. The residuum, amounting to 58,75 parts, was dissolved in water; and being treated with muriate of barytes, 15 parts of sulphate of barytes precipitated, indicating the presence of about .5 of sulphuric acid, or 0.75 sulphate of potash. The remaining 58 parts were muriate of potash, indicating about 21 parts of muriatic acid.*

METHOD OF SEPARATING SILVER FROM COPPER.

It is a valuable discovery of Mr. Keir, that a mixture of strong sulphuric acid with the nitrous acid, or nitrate of potash, is a powerful solvent of silver, though it scarcely acts upon the other metals. This is of considerable importance in the Birmingham manufactures, where the silver in the cuttings of plated copper is required to be separated from this last metal. For this purpose the pieces of metal are put into a glazed earthen pan, and a composition of eight or ten pounds of sulphuric acid, with one pound of nitrate of potash, is poured upon them, stirred, and the action of the fluid assisted by a heat between 100 and 200° Fahr. When the liquor is nearly saturated, the silver is to be precipitated by common salt, which may be easily afterwards reduced; or, otherwise, the silver may be precipitated in its metallic state by adding to the solution a few of the pieces of copper, and a sufficient quantity of water, which enables the liquor to act on the

* Klaproth's Beitrage, i. 132.

copper. The theory of this effect still remains to be investigated.

The method of obtaining pure silver has been noticed already.

The standard silver of Great Britain contains 15 parts of silver and one of copper.

In the solder used to join different parts of silver utensils, this proportion of copper is considerably greater; hence it is that such vessels are apt to oxydate, or become covered with a green oxyd at the places where they are soldered.

[Oxyd of silver when fused with glass, gives a bright olive yellow colour. Solutions of silver, stain animal and vegetable substances of a brownish black colour, and hence it is used to stain ivory, bone, wood, marble, hair, &c. T. C.]

COPPER.

PART XXXVII.

SECT. I.

NATURAL HISTORY OF COPPER.

COPPER is found in the earth in various states. It is found native *(native copper)* possessing the red colour, malleability, and many of its other properties; it is however not quite pure, but generally mixed with a minute portion of gold or silver.

This ore is found of an indeterminate figure in solid and compact masses; sometimes in plates and threads, which assume a variety of forms. It crystallizes in cubes. It then is flexible. It has much metallic lustre. It is found in many parts of Europe.

Copper ores are very numerous. Copper combined with oxygen forms *oxyd of copper*, or the *earthy copper ore (mountain blue.)* United to carbonic acid it constitutes the hepatic copper ores *(mountain green)* &c. The compact ore of this kind is termed *malachite.*

This ore generally exhibits a very fine grass-green, emerald-green, or apple-green colour. It is found in solid masses of an indeterminate shape. It has often a beautiful satin-like appearance, or silky lustre.

It also exists mineralized by muriatic acid, sulphuric acid, arsenic acid, &c. Copper mineralized with sulphur is called *vitreous copper ore.* Its colour is generally lead-grey. Combined with sulphur and iron it forms the *azure copper ore*, and all the varieties of copper pyrites. Mineralized with sulphur, arsenic, iron and zinc, it constitutes

the *brown* or *blendose copper ores*, of which there are many varieties. Copper mines are abundant in Britain, Germany, &c.

PROPERTIES OF COPPER.

Pure copper is of a rose-red colour, very sonorous, very tenacious, ductile, and malleable; of a considerable compactness; moderately hard and elastic. Its texture is granulated, and subject to blisters. It crystallizes in quadrilateral pyramids. Its specific gravity is between 7.788 and 8.534.* When rubbed it emits a disagreeable odour. It melts at 27° of Wedgwood's pyrometer. At a higher temperature it burns with a beautiful green flame. It is a good conductor of caloric, of electricity, and of galvanism. Exposed to the air it becomes brown and at last green, by absorbing carbonic acid. When heated it turns blue, yellow, violet, and brown. It readily fuses with phosphorus, and unites to sulphur when finely divided by mere trituration. It does not decompose water at the temperature of ignition. It is acted on by the greater number of the acids. Nitric acid acts on copper with great vehemence. Sulphuret of potash combines with it in the dry and in the humid way. It is capable of alloying with the greater number of the metals. With zinc it forms the compound metals called brass, pinchbeck, and others; with tin it forms bell-metal and bronze. It unites to the earths merely in vitrification. Liquid ammonia causes it to oxydate quickly when air is admitted. It decomposes muriate of ammonia and red sulphurated oxyd of mercury by heat. It is poisonous to the human constitution.

METHOD OF OBTAINING COPPER.

Copper is procured from its ores by different processes, according to the nature of those ores. If they contain much sulphur, after being pounded and washed, they are roasted in the open air to dispel the sulphur. The ore is afterwards roasted once or twice more, and is melted in an open fire into a mass, called a mat of copper. In this state it still contains a large quantity of sulphur, which

* 8.89. DAVY.

the workmen continue to expel by repeated roastings and fusion, till the metal acquires a certain degree of purity, and is called black copper, which is somewhat malleable, but still contains sulphur, iron, and in general some other impurities. In order to get entirely rid of these, the copper is hastily fused with three times its weight of lead. The lead unites with the copper, and expels the iron; and the rest of the metals which happen to be mixed with the copper are thus expelled. The copper is afterwards refined by keeping it heated in crucibles for a considerable time, so that it may throw up all the foreign substances it still contains in the form of scoriæ. It is examined from time to time by immersing iron rods into it, which become coloured with a small quantity of copper, and its purity is judged of by the brilliant redness of these specimens.*

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF COPPER.

Experiment I.

Copper dissolves readily in diluted nitric acid.

(Preparation of nitrate of Copper.)

LET copper filings be dissolved in a sufficient quantity of nitric acid of a moderate strength; when no further effervescence ensues boil the acid gently upon the copper until a pellicle appears. Decant the solution and evaporate it slowly, and when a strong pellicle is formed suffer it to crystallize. The salt thus obtained is of a fine blue colour.

Experiment II.

Action of liquid ammonia on copper.

A singular phenomenon which attends the action of liquid ammonia on copper has long attracted the notice of chemists.

If a bottle, provided with a ground stopper, be filled quite full of liquid ammonia, and some copper filings be

* Pure copper for chemical experiments may be procured by dissolving common copper in muriatic acid, precipitating it by iron, and washing the precipitate in dilute muriatic acid. Davy.

introduced, and the bottle immediately stopped without including any air, no solution will take place. On the contrary, if the bottle be left open for some time, and then closed, a solution is effected, which is absolutely colourless, but turns blue on re-opening the bottle, beginning at the surface, and gradually extending downwards through the whole mass. Again, if this blue solution has not been too long exposed to the air, and fresh copper filings be put in, stopping the bottle again, the solution is deprived of all its tinge, and recovers its colour only by the admission of air. And this effect may be produced repeatedly.

RATIONALE....Metallic copper, as such, is not acted upon by liquid ammonia, but is soluble when oxydated. This oxydation is effected by the influence of oxygen when atmospheric air is admitted. Hence, when the copper is no farther oxydated than is necessary for solution, this is colourless; but it acquires a blue colour when the metal is oxydated in a higher degree. It is also obvious that this azure colour is again destroyed by the addition of more copper filings and exclusion of air, as the newly added metal deprives that which was contained in the solution in an oxydated state of its super-abundance of oxygen, in order to be dissolved also in the liquid.

EXPERIMENT III.

Copper combines with phosphorus.

(Preparation of phosphuret of copper.)

Mix together equal parts of fine copper filings and glacial acid of phosphorus, add one-eighth part of charcoal powder, and then fuse the whole in a Hessian crucible. The prodnct will be a metallic button of a whitish appearance, which sometimes exhibits the prismatic colours.

EXPERIMENT IV.

Copper combines with sulphur both in the humid and in the dry way.

(Preparation of sulphuret of copper.)

Take equal quantities of copper filings and sulphur, and having formed them into a soft paste, by the addition of a

sufficient quantity of water, expose the mixture to the air; lixiviate it at the end of some days, and sulphate of copper will be obtained by crystallizing the lixivium.

A sulphuret of copper may be obtained by putting into a crucible alternate strata of thin plates of copper and sulphur in powder. The crucible is then to be exposed to a gradual heat, in a furnace, till no more vapours issue from it. Keep the crucible in a dull red heat for an hour, and then suffer it to cool. The product will be a sort of copper slag, brittle, and of an iron colour, which when worked exhibits the colour of green oxyd of copper.

Experiment V.

Copper unites readily with zinc, and forms a compound, called brass.

Brass is produced by the following processes: Put into a crucible four parts of granulated copper and six or eight of zinc, and nearly fill the crucible with charcoal-powder, cover it and bring it briskly to a red heat; the copper will unite with the zinc, and form brass.

If plates of copper be cemented with native oxyd of zinc reduced to powder, and mixt with charcoal also in powder; by bringing the mixture to a red heat in a covered crucible, the copper and zinc will unite, and likewise form brass.

Brass is made in the large way by a process similar to this.

Tombac is obtained in a like manner by fusing together in a crucible twelve parts of copper and three of zinc.

Gun-metal is said to consist of copper alloyed with one-tenth part of tin.

Bell-metal is copper alloyed with about one-sixth of tin: it may in general be observed that a less proportion of tin is used for making church-bells than clock-bells, and that a little zinc is added for the bells of repeating watches, and other small bells.

The metal of which *cocks* are in general made is copper alloyed with zinc and lead.

Experiment VI.

Concentrated sulphuric acid only acts upon copper at elevated temperatures.

Pour upon one ounce of copper filings in a matrass two ounces of concentrated sulphuric acid, there will be no

action in the cold; but if the matrass be placed on a sand-bath, and a degree of heat applied nearly sufficient to make the acid boil, the copper will be gradually dissolved, and sulphureous acid gas will be liberated.

Experiment VII.

Copper unites with arsenic acid, and forms a compound called Scheele's green.

This colour is formed by decomposing sulphate of copper by the arseniate of potash, in the following manner:

Dissolve potash in water with heat; add white oxyd of arsenic or arsenic acid to the point of saturation, and filter the liquor. Then take a warm solution of sulphate of copper, and pour it into the arseniate of potash: a little only must be added at a time, and it must be continually stirred with a glass rod. Leave the mixture at rest till a precipitate is formed; then decant the liquor, and having washed the residuum repeatedly in warm water, filter it, and leave it to dry. By this process a beautiful green colour is obtained.

As this colour is not alterable by air, it is employed in painting.

Experiment VIII.

Preparation of blue verditer.

To a solution of nitrate of copper add pulverized lime, and shake the mixture to facilitate the decomposition. A little excess of nitrate of copper should be used, that the whole of the lime may be saturated, and that the precipitation formed at the moment of mixture may be a pure precipitation of copper; the precipitate is suffered to settle, after which the super-natant fluid is decanted, and the residuum being repeatedly washed is deposited on a piece of cloth to drain.

It is from this precipitate, which is of a delicate green colour, that the blue verditer is prepared.

For this purpose grind it on a colour-stone, or in a large mortar with a little quick-lime. This mixture acquires, in a moment, by trituration, a very lively blue colour.

The quantity of lime necessary is about four or five per cent. of the precipitate.

If the precipitate is too dry, add a very small quantity of water, in order that the mixture may form a paste somewhat liquid, and easy to be pounded.

The whole must be afterwards dried.

REMARK....There are two kinds of verditer in the market; the one, called *refiners' verditer*, has the form of a very soft, impalpable powder, and possesses a stronger body of colour than the other, which is in harsh, irregular lumps, not easily diffusible in water.

The best verditer is at present made only by the refiners: they obtain the nitrous solution of copper at a cheap rate during the process of parting; the value of the article not admitting of the direct application of nitrous acid to copper. The common verditer is made by decomposing sulphate of copper by means of lime. A comparative analysis of both articles has shown that the verditer obtained in this manner is always contaminated with a considerable quantity of oxyd of iron and sulphate of lime; both admixtures arising probably from the impurity of the sulphate of copper employed, and the difficult solubility of the sulphate of lime formed in the process. These objects are well worthy of being attended to, for the article is of considerable commercial importance.

ANALYSIS OF ORES OF COPPER.

In order to analyse *sulphuret of copper*, let one part of the ore, reduced to powder, be digested, or extracted, with three or four of nitric acid by heat, as long as it will take up any of the ore; then filter the whole, and wash the insoluble residue, which for the greatest part consists of sulphur. Its quantity may be ascertained by subliming it by heat, or by burning it in the open air. It becomes thus partly converted into sulphuric acid. The residue may be diluted with water, and then decomposed by the addition of nitrate of barytes. The insoluble precipitate, when dry, contains 14.5 of sulphur.

In order to separate the iron, let the solution be boiled down to dryness, re-dissolved in nitric acid, and evaporated to dryness again repeatedly; the iron will then be separated in the form of a red oxyd when water is added to

the solution. To ascertain the quantity of copper which was contained in the ore, the solution from which the iron is separated must be decomposed by the addition of a solution of potash. The precipitate, after being dried in a red heat, is black oxyd of copper. One hundred parts of it contain 80 of metallic copper.

Red copper ore may be dissolved in muriatic acid, and then immersing into this solution polished plates of iron, so long as a film of copper is precipitated upon them; 88 parts of the precipitated copper being equivalent to 100 of the oxyd of which the ore is composed.

Arseniate of copper was analyzed by Chenevix* in the following manner:

The ore was dissolved in diluted nitric acid, and then decomposed by nitrate of lead. The solution was evaporated till a precipitate began to appear, and then mingled with alcohol. The product which became precipitated was arseniate of lead; 100 parts of which indicate 33 of arsenic acid. The copper must then be separated from the nitric acid by boiling it with potash, as directed above.

Native copper sometimes contains gold, silver, or iron. If the ore therefore be dissolved in nitric acid, the gold will not be acted upon by this acid, but the other metals will be dissolved. The silver may be separated by immersing into the solution a polished plate of copper, (or it may be precipitated from a separate portion of the solution by muriatic acid, or common salt) the iron may be separated by boiling the solution to dryness, and treating the residuum with water. By this process the nitrate of iron is decomposed; the oxyd of iron remains, while the water dissolves the nitrate of copper. This nitrate may be decomposed by boiling it with potash, and its quantity of metal estimated as stated above.

In order to obtain pure copper, let the copper of commerce be dissolved in muriatic acid, and precipitate it by a polished plate of iron; or the black oxyd of copper obtained by decomposing cuprated ammonia may be melted with its own weight of pounded glass and pitch.†

* Philosoph. Trans. 1801, p. 195.

† There are two oxyds of copper, one containing 11 and the other 20 per cent. of oxygen, according to Davy. It has not been combined with hydrogen, azot or carbon. Davy.

IRON.

PART XXXVIII.

SECT. I.

NATURAL HISTORY OF IRON.

OF all the metals there is none which is so copiously and so variously dispersed through nature as iron. In animals, in vegetables, and in all parts of the mineral kingdom we detect its presence, Mineralogists are not agreed with respect to the existence of native iron, though immense masses of it have been discovered, which could not have been the products of art; but there is much in favour of the notion that these specimens have been extracted by subterraneous fire. A mass of native iron, of 1600 pounds weight, was found by Pallas, on the river Denisei, in Siberia; and another mass of 300 pounds was found in Paraguay, of which specimens have been distributed every where. A piece of native iron, of two pounds weight, has been also met with at Kamsdorf, in the territories of Neustadt, which is still preserved there. These masses evidently did not originate in the places where they were found.

There are a vast variety of iron ores; they may, however, be all arranged under the following genera, namely, sulphurets, carburets, oxyds, and salts of iron. The sulphurets of iron form the ores called *pyrites*, of which there are many varieties. Their colour is in general a straw-yellow, with a metallic lustre. They are often amorphous, and often also crystallized. Iron ores of this kind are known by the name of *mundick*. Iron in the state of a

carburet forms the *graphite* of Werner *(plumbago.)* This mineral occurs in kidney-form lumps of various sizes. Its colour is a dark iron gray, or brownish black; when cut, blueish gray. It has a metallic lustre. Its texture is fine grained. It is very brittle. The combination of iron with oxygen is very abundant. The common *magnetic iron stone*, *magnetical pyrites*, or *load-stone*, belongs to this class: as does *specular iron ore*, and all the different ores called *hematites*, or *blood-stone*. Iron, combined with silex, constitutes emery. Iron, united to carbonic acid, exists in the *sparry iron ore*. Joined to arsenic acid it exists in the ores called *arseniate of iron*, and *arseniate of iron and copper*.

PROPERTIES OF IRON.

Iron is distinguished from every other metal by its magnetical properties. It is attracted by the magnet, and acquires, under various conditions, the property of magnetism. Pure iron is of a whitish gray, or rather blueish, colour, very slightly livid; but when polished, it has a great deal of brilliancy. Its texture is either fibrous, fine grained, or in dense plates. Its specific gravity varies from 7.6. to 7.8. It is the hardest and most elastic of all the metals. It is extremely ductile, and may therefore be drawn into wire as fine as a human hair; it is also more tenacious than any other metal, and consequently yields with equal facility to pressure.* It is extremely infusible, and when not in contact with the fuel it cannot be melted by the heat which any furnace can excite: it is, however, softened by heat, still preserving its ductility; this constitutes the valuable property of *welding*. It is very dilatable by heat. It is the only metal which takes fire by the collision of flint. Heated by the contact of air it becomes oxydated. If intensely and briskly heated, it takes fire with scintillation and becomes a black oxyd. It combines with carbon, and forms what is called steel. It combines with phosphorus in a direct and in an indirect manner, and unites with sulphur readily by mixture in the cold with water, and by fusion. It decomposes water, in the cold slowly, but rapidly when ignited. It decomposes most of the metallic oxyds. All acids act upon iron. Very concentrated sulphuric acid

* A wire .078 inch diameter, supports 549½ lbs. DAVY.

has little or no effect upon it, but when diluted it oxydates it rapidly. The nitric acid oxydates it with great vehemence. Muriate of ammonia is decomposed by it. Nitrate of potash detonates very vigorously with it. Iron is likewise dissolved by alkaline sulphurets. It is capable of combining with a number of metals. It does not unite with lead or bismuth, and very feebly with mercury. It detonates by percussion with the oxygenated muriates.

METHOD OF OBTAINING IRON.

The general process by which iron is extracted from its ores, is first to roast them by a strong heat, to expel the sulphur, carbonic acid, and other mineralizers which can be separated by heat. The remaining ore, being reduced to small pieces, is mixed with charcoal, or coke, and is then exposed to an intense heat in a close furnace excited by bellows; the oxygen then combines with the carbon, forming carbonic acid gas during the process, and the oxyd is reduced to its metallic state. There are likewise some fluxes necessary, in order to facilitate the separation of the melted metal. The matrix of the iron ore is generally either argillaceous or calcareous, or sometimes a portion of siliceous earth; but whichever of these earths is present, the addition of one or both of the others makes a proper flux. These are therefore added in the due proportion, according to the nature of the ores; and this mixture *in contact with the fuel*, is exposed to a heat sufficient to reduce the oxyd to its metallic state.

The metal thus obtained, and called smelted, pig, or cast iron, is far from being pure; always retaining a considerable quantity of carbon and oxygen, as well as several heterogeneous ingredients. According as one or other of these predominates, the property of the metal differs. Where the oxygen is present in a large proportion, the colour of the iron is whitish gray; it is extremely brittle, and its fracture exhibits an appearance of crystallization: where the carbon exceeds, it is of a dark gray, inclining to blue or black, and is less brittle. The former is the *white*, the latter the *black crude iron of commerce*. The *gray* is intermediate to both. In any of these states, the iron is much more fusible than when pure: hence it can be

fused and cast into any form; and when suffered to cool slowly, it crystallizes in octahedra: it is also much more brittle, and cannot therefore be either flattened under the hammer, or by the laminating rollers.

To obtain the iron more pure, or to free it from the carbon with which it is combined in this state, it must be refined by subjecting it to the operations of melting and forging. By the former, in which the metal is kept in fusion for some time, and constantly kneaded and stirred, the quantity of carbon and oxygen it contains are combined, and the produced carbonic acid gas is expelled: the metal at length becomes viscid and stiff; it is then subjected to the action of a very large hammer, or to the more equal, but less forcible pressure of large rollers, by which the remaining oxyd of iron and other impurities not consumed by the fusion, are pressed out. The iron is now no longer granular, or crystallized in its texture; it is fibrous, soft, ductile, malleable, and totally infusible. It is termed forged, wrought, or bar-iron, and is the metal in a purer state, though far from being alsolutely pure.

Remark. There are several varieties of this iron arising from the intermixture of other substances. There is one kind of forged iron, which, when cold, possesses ductility; but when heated, is extremely brittle; it is also fusible: this is termed *hot short iron.* Another variety, the *cold short iron*, possesses precisely the opposite properties being highly ductile while hot, but when cold extremely brittle. The causes of these peculiarities have not perhaps been perfectly explained. Chemists are generally agreed that the property of cold short iron depends on the presence of a substance termed *siderite*, once considered as a peculiar metal, but now known to be a compound of phosphoric acid and iron: that of hot short iron has been ascribed to the intermixture of arsenic, sulphur, or sulphureous acid; but the real cause is not well ascertained.

PROPERTIES OF STEEL.

Steel is of a light gray colour: its fracture is finely granulated, and brilliant; and it is susceptible of a very high polish. It is fusible by itself. It is both ductile and mal-

leable, and when hammered, has a specific gravity greater than that of iron. The property by which it is eminently distinguished is, that of acquiring a degree of hardness by being hastily immersed in cold water when red-hot; the hardness being proportioned to the heat of the steel, and the coldness of the water. This is what is termed *tempering* of it, the requisite degree of hardness being given by attending to the degree of heat which the metal acquires, and suffering it to cool accordingly. It may be made so hard as to scratch glass, and at the same time it becomes more brittle and elastic. Steel thus hardened may have its softness and ductility restored to it, by again heating it, and suffering it to cool slowly.

The colours which a polished piece of steel acquires by being heated with access of air, are far brighter than those with which the other species of iron tarnish in the same situation. It first becomes of a straw-yellow, then of a higher yellow, next purple, then violet, next red, then deep blue, and at last bright blue. At this period it becomes red-hot, and the colours disappear, at the same time that the metallic scales, or the black imperfect oxyd of iron which is formed, incrust its surface. All these different shades of colour indicate the different tempers the steel has acquired by the increase of heat. Mr. Stodart has availed himself of this property to give to surgical, and other cutting instruments, those degrees of temper which their various uses require, and his attention to this circumstance has rendered his tools so justly celebrated.

Steel possesses a degree of hardness superior to any other metal. It affords sparks with flint. It may be hammered out into much thinner plates than iron, and is more sonorous. It is also possessed of the greatest elasticity, and is perhaps the most useful of all metals.

METHODS OF CONVERTING IRON INTO STEEL.

To form steel, bars of malleable iron are bedded in charcoal in a close furnace, alternate layers of iron and charcoal being formed. A strong fire is applied for six or eight days: the progress of cementation, as this pro-

cess is termed, is known by drawing a trial bar from the furnace; if this is sufficiently changed the fire is extinguished, and the metal left to cool for some days. This forms *blistered steel.* It is rendered more perfect by subjecting it to the operation of the hammer, as in forging iron; or it is fused, and cast into small bars, forming what is termed *cast steel.* These operations are performed on malleable iron; but those kinds of cast iron which contain little oxygen can be converted into steel by a similar process.

In this operation an increase of weight from $\frac{1}{180}$th to $\frac{1}{140}$th is gained. The more carbon is introduced, the more fusible and more brittle is the steel. Bergman first showed clearly the presence of this matter, ascertaining by experiments that less hydrogen gas is disengaged during the solution of steel in diluted sulphuric acid, than during the solution of iron in the same acid; and that during the solution of the steel, carbon is precipitated in the form of plumbago. Morveau has justly observed that it is pure carbon, not its oxyd, that is present in steel; and to this its great hardness may be ascribed. Bergman further found, that some specimens of steel contained manganese and silex; and Vauquelin has likewise discovered the existence of this earth, and of phosphorus, in several kinds of steel which he analysed.

CLOUET'S METHOD OF MAKING CAST STEEL.

A new method of preparing cast steel has been lately announced in France by Clouet. His process is the following: Take small pieces of iron and place them in a crucible, with a mixture of the carbonate of lime and the earth of Hessian crucibles; six parts of the carbonate of lime and six of this earth must be employed for twenty parts of the iron. The matters are to be so disposed, that after fusion the iron must be completely covered by them, to prevent it from coming into contact with the external air. The mixture is then to be gradually heated, and at last exposed to a heat capable of melting iron. If the fire be well kept up, an hour will generally be sufficient to convert two pounds of iron into excellent and exceed-

ingly hard steel, capable of being forged; an advantage not possessed by steel made in the common manner.*

Metallurgy therefore comprehends three arts relative to iron; namely, its first fusion into crude iron; the change of this into bar-iron; and its conversion into steel.

The cause of the difference between crude iron, malleable iron, and steel, consists partly in this; that this metal may still appear in its metallic state though it is slightly oxydated; and partly that it is capable of combining with different quantities of carbon.

Crude iron is not yet absolutely and perfectly deoxydated, or reduced to the complete metallic state: it also holds a considerable portion of carbon in combination, the *gray* containing a greater quantity than the *white* crude iron.

Malleable iron is not only perfectly metallic, but likewise uncontaminated by carbon. It is a simple substance, and if perfectly pure would contain nothing but iron. It however is, strictly speaking, never absolutely pure.

Steel is iron combined with carbon; it has for that reason been called *carbonated iron.* The proportion of carbon has not yet been ascertained with accuracy.

Cast iron is iron combined with a much larger quantity of carbon than is necessary for forming steel.

METHOD OF DISTINGUISHING IRON FROM STEEL.

Rinman has long ago pointed out a ready method by which steel may be distinguished from iron. When a little diluted nitric acid is dropped upon a plate of steel, allowed to remain for a few minutes, and then washed off, it leaves behind it a black spot; whereas the spot formed by nitric acid upon iron is whitish gray.

RATIONALE....The colour of the black spot is owing to the carbon of the iron, which is converted into charcoal by the acid, and in that state is distinguishable by the eye. Whereas upon iron which is nearly free from carbon this effect cannot take place.

* Phil. Mag. vol. II. p. 219. But Mushet has shewn that this process does not succeed in a common crucible, though it will in a black lead crucible. T. C.

REMARK....This experiment shows that carbon is much more readily oxydated when combined with iron, than when crystallized in the form of diamond.

INFERENCES.

From what has been stated above it is easy to comprehend why good gray *crude iron* is converted into steel by simple fusion either by itself or with the black oxyd of manganese, lime, and other such matters. Why it retains the nature of crude iron when fused under charcoal dust. Why by successive ignitions it becomes progressively more ductile and more difficultly fusible. Why it yields ductile iron if melted with oxyd of iron. Why *ductile iron* when fused with and under a stratum of powdered charcoal may be converted either into crude iron or into steel. Why ductile iron becomes steel by cementation with charcoal. Why ductile iron is never changed into steel by mere igniting and forging; and finally, why ductile iron may in some manner assume the nature of steel, if it be smelted with black lead under a cover of powdered charcoal.

The habitudes of the different varieties of iron that have till now occupied our attention are not confined within narrow limits; and for this reason there are innumerable gradations to be met with, beginning from the black crude iron, to the most pure and ductile bar-iron.

The knowledge, treatment, and modification of iron in its different states have great influence on the happiness and power of nations. The perfection of iron-works follows the degree of the civilization of man. Under the form of cast-iron, it serves to construct numbers of machines and utensils. In bar-iron it serves for innumerable purposes: it unites force and resistance to flexibility and spring. In steel it is fitted not only for the grossest purposes of mechanical machinery, but also for those which are the nicest and most delicate, as we see in the instruments of anatomists, engravers, &c. for which uses the other metals, on account of their inferior hardness, cannot be employed. The capability of acquiring the still inexplicable property, called the magnetic power, has given birth to an important instrument, which has opened inexhaustible sources of in-

dustry and wealth to nations; the mariners compass; yet in its non-metallic state its uses are many and incalculable. For instance, it is capable of yielding the most beautiful colours, Prussian blue, black dyes, &c. In medicine it renders services equally numerous and important.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF IRON.

EXPERIMENT I.

Iron combines with sulphur by heat.

Mix one part of iron filings with two of sulphur, and fuse the mixture in a covered crucible as quickly as possible. The product will be *sulphuret of iron*, which is of a black or very deep gray colour, brittle, and remarkably hard.

Sulphuret of iron may also be formed by applying a roll of sulphur to the end of an iron bar brought to a white heat; both of them will be fused, and the sulphuret will fall down in drops.

When sulphuret of iron is reduced to powder, and moistened with water, the sulphur is gradually converted into sulphuric acid by absorbing oxygen, while at the same time the iron becomes oxydated.

EXPERIMENT II.

Iron enters into combination with phosphorus.

Mix equal parts of iron filings, and glacial acid of phosphorus, and fuse the mixture in a covered crucible, with half a part of charcoal powder. A very brittle button will be obtained, white on the fracture, and having a striated and granulated appearance: it sometimes crystallizes in rhomboidal prisms. This is *phosphuret of iron.*

It may also be formed without the interposition of charcoal, by merely fusing together equal parts of glacial acid of phosphorus and iron filings.

RAITONALE....In the first case the charcoal subtracts the oxygen from the phosphoric acid, and re-converts it into phosphorus, which, in its nascent state, combines with the iron; in the second case part of the iron combines with the oxygen of the phosphoric acid and becomes vitrified, and the rest forms the phosphuret, which sinks to the bottom of the crucible.

EXPERIMENT III.

Iron decomposes sulphuret of antimony.

Bring five parts of iron filings to a red heat in a crucible, and then introduce sixteen parts of powdered sulphuret of antimony. Expose the mixture to a sudden and strong heat, and the iron will attract the sulphur. When the mixture is thoroughly fused, project, gradually, one part of nitrate of potash in powder, which will greatly facilitate the separation of the scoriæ from the antimony. The product will be antimony in its metallic state, which does not contain iron. If, however, one part of iron be made use of with two of sulphuret of antimony, a little iron will remain united with it. This was formerly called *martial regulus*.

EXPERIMENT IV.

Combination of iron with mercury.

Though iron combines with most metals, its union with mercury could not be effected until lately. Mr. Arthur Aikin succeeded in producing an alloy of iron and mercury.* The method which this gentleman recommends for that purpose consists in uniting an alloy of zinc and mercury with iron filings, and then adding muriate of iron; a decomposition takes place, and there is produced a muriate of zinc, and an alloy of iron and mercury, which by kneading, and the aid of heat, assumes a metallic lustre.

* Philosoph. Mag. 1802. No. LII. p. 406.

Experiment V.

Iron combines with oxygen in two different proportions only.

We have noticed already, that iron burns with great splendour and rapidity in oxygen gas, and is at the same time converted into an oxyd. But it is capable, by other processes, of combining with two different portions of oxygen, and these oxyds are possessed of qualities essentially different from each other. These are the *black*, or the *green*; and the *red*, or the *brown* oxyd of iron.*

To illustrate this, let a bar of iron be brought to a red-heat; on cooling, its surface will be covered with thin scales, which separate by the blow of a hammer. If this process be continued, the whole bar may be converted into such scales, which are called *forged scales of iron*, or more properly *black oxyd of iron*. This is an *imperfect* oxyd of iron; it contains about 27 per cent. of oxygen, and is obedient to the magnet.

If the imperfect oxyd of iron, obtained in this process, be reduced to powder, and exposed to a white heat in a crucible, or under a muffle, stirring it frequently, it will become reddish brown. This is the *red*, or *brown oxyd of iron*. It is a *perfect* oxyd, containing about 48 per cent. of oxygen, and is not affected by the magnet. This oxyd, ignited with charcoal, loses part of its oxygen, and becomes re-converted into the black oxyd of iron; the same is the case when submitted to the action of sulphurated hydrogen gas.

The black, or green oxyd of iron, may also be obtained by keeping iron filings for a length of time in water, at a temperature of about 70°. The oxyd thus formed is a black powder, formerly known by the name of *martial ethiops*. It is likewise obtained by making steam pass through a red-hot iron tube, or by burning iron in oxygen gas, or by decomposing a solution of sulphate of iron by the addition of potash, and drying the precipitate expeditiously in a close vessel.

The red, or brown oxyd of iron, may also be formed by keeping iron-filings red-hot in an open crucible, and agitating them constantly, till they are converted into a dark red powder, formerly called astringent saffron of mars.

* Rather the brown-red oxyd. T. C.

It may also be produced by exposing a solution of iron in sulphuric acid for a long time to the atmosphere; or rather by pouring into it nitric, or oxygenated muriatic acid.

REMARK....We are indebted to Proust for an excellent memoir concerning the combination of oxygen with iron: in which he has illustrated in a very satisfactory manner, that metals are not capable of indefinite degrees of oxydation, but only of a certain number, and that every particular oxyd consists of a determinate quantity of the metal, and oxygen chemically combined.

The metal under consideration, for instance, is not capable, as was formerly supposed, of uniting with oxygen in all the intermediate degrees, between 0.27 and 0.48.

It can only combine with, *precisely*, 0,27 parts, or 0.48 parts, and *with no other proportion*; and therefore is only capable of forming the two oxyds considered before.

To talk therefore of oxydating a metal indefinitely is not accurate, except it be intended to signify the combining of part of it with oxygen, while the rest remains in its natural state.

If, therefore, iron be oxydated at all, it *must be* combined with 0.27 of oxygen; if it be oxydated more than this, it must be combined with 0.48 of oxygen.

In like manner every other metal, as we have seen already, combines with certain proportions of oxygen and forms either two or more oxyds, according to its nature.

Whenever metals are capable of forming more than one oxyd, it is only the first oxyd, or that which contains a *minimum* of oxygen, which is formed by the direct combination of oxygen with the metal; for oxygen is capable of uniting with metals, or with any other substance for which it has an affinity, only in *one* determinate proportion.

Iron, for instance, and oxygen can only combine in the proportion of 73 parts of iron, and 27 of oxygen. These two quantities saturate each other, and form a compound which is incapable of receiving into it any more oxygen or iron: this compound is the *black or green oxyd of iron.*

How comes it then, it will be asked, that there is another oxyd of iron, the *brown* or *red oxyd*, which contains 52 parts of iron, and 48 of oxygen, proportions certainly very different from 73 and 27? Because there is an affinity

between the green and black oxyd of iron and oxygen. They are capable of combining together, and of saturating each other in the proportion of about 71.5 parts of black oxyd, and 21.5 of oxygen, and the compound which they form is the *brown*, or *red oxyd*, which of course contains 52 parts of iron, and 48 of oxygen: But then it is not formed by the combination of these two substances directly, but by the combination of the black oxyd and oxygen. In like manner lead and oxygen combined form gray oxyd of lead; gray oxyd of lead and oxygen combined form white oxyd; white oxyd of lead and oxygen combined form red oxyd; which last oxyd, when combined with oxygen, forms the brown oxyd of lead.

That this is the case cannot be doubted, if we consider that, in general, every one of these successive doses of oxygen is retained by a weaker affinity than the dose which precedes it. Thus the brown oxyd of iron is composed of iron, and two doses of oxygen. The first dose amounts to 0.37, the second to 0.56 of the iron. Consequently,

Iron. Oxygen. Black oxyd.
$$1 + 0.37 = 1.37$$
Oxygen. Brown oxyd.
$$1.37 + 0.56 = 1.93.$$

If the second dose of oxygen be abstracted, there will remain behind 1.37 of black oxyd. If both doses be abstracted, there will remain behind 1 of pure iron. If both these doses adhere to the iron with the same force, it is obvious that every substance which is capable of abstracting one of these doses would be capable also of abstracting both, provided it be employed in sufficient quantity. But it is a fact that many substances are capable of abstracting the second dose of oxygen, which have no action on the first dose.

If hydrogen gas, for instance, be made to pass through brown oxyd of iron, heated to redness in a porcelain tube, it converts it into black oxyd of iron, and consequently deprives the iron of its second dose of oxygen. But it produces no change upon the black oxyd in similar circumstances. Hydrogen gas is therefore capable of depriving iron of its second dose of oxygen only.

These observations apply equally to the oxyds of other metals. The subject is of the highest importance, and must be more fully investigated before the action of the metals and their oxyds upon oxygen and upon each other can be understood.

For if equal parts of iron, and the red oxyd of iron, are heated together, the whole is converted into the black oxyd. This is the case, because the iron having a stronger affinity for oxygen than that of the red oxyd for its second dose, the oxyd is deprived of that quantity of its oxygen, and they are both converted into iron, oxydated at its *minimum* or black oxyd of iron: but whence arises a sufficiency of oxygen to oxydate the whole of the iron?

If we suppose 193 parts of red oxyd and 193 parts of iron to be heated together: 193 parts of red oxyd are composed of 137 black oxyd + 56 oxygen: 193 parts of iron, to be converted into black oxyd, require 71 parts of oxygen; but the second dose, which they can alone attract, consists of only 56 parts, consequently 15 parts of oxygen are wanting. This small portion must either be supplied by the atmosphere, or 55 parts of the iron must remain uncombined with oxygen.*

ANALYSIS OF ORES OF IRON.

As to the manner of assaying iron ores, for the purpose of making a calculation of the quantity of metal which may be extracted from the ore, if to be wrought on a large scale, the following methods have been found to answer the end very accurately:

A certain quantity of the ore which is to be assayed is first reduced to small particles, and torrefied by a gentle heat, not stronger than is required to separate the moisture, and to volatilize the sulphur, if the ore contains any, which is easily perceived by the smell during the torrefaction. When the moisture and sulphur are separated, four parts of the remaining ore are to be mixed with an equal quantity of common salt, or *muriate of soda (which has been previously deprived of its water of crystallization by stirring it in a flat earthen vessel over fire)* and with the same quantity of a mixture of equal parts of fluor spar and lime, and half a part of charcoal. This mixture is kept red-hot in a crucible, covered with charcoal,

* This is a proof that the properties of oxygen in the oxyds are not yet accurately ascertained. Indeed, from the very nature of the experiments, nothing but approximations can be expected. Accum.

The black oxyd produces pale green solutions; the brown-red oxyd yellow solutions in acids. Triple prussiate of potash, precipitates the former solutions white, the latter or yellow solutions, blue. Davy.

There have been no combinations of iron with hydrogen or azot. Davy.

for $\frac{3}{4}$ of an hour, after which the iron contained in that quantity of ore is found in a metallic state in the bottom of the crucible.

Or, four hundred grains of sub-borate of soda, 40 grains of slacked lime, and 200 grains of the ore to be assayed, are mixed together. The mixture is pulverized, and placed in a lined crucible, which is to be covered. The heat of a forge-furnace is then sufficient to effect the reduction of the metal, which is generally done in the course of half an hour.

The moist or humid way of assaying the ores of iron, is attended with more difficulty. The following method is the most simple: A certain quantity of iron ore is reduced to powder, and digested with about six parts of muriatic acid, which takes up the iron, and such earths as are soluble in that acid, and leaves the silex and the sulphur behind; after which, the solution is to be saturated with potash, (or if the ore contains any copper, with ammonia) which precipitates the iron in the state of an *oxyd*, along with the dissolved earths; the precipitate is then well dried, and strongly heated to redness, after which it is pulverized, and put in digestion with nitric acid, which takes up all the earths, together with the other heterogeneous substances, and leaves the iron behind, which, on account of its being so highly oxydated, loses its solubility in that acid; it is then well washed, freed from the acid, and afterwards recovered by charcoal, or any other inflammable matter which has a stronger affinity to the oxygen than the iron; the metal found in the bottom of the crucible indicates the proportion of the metal contained in a given quantity of the ore.

Arseniate of iron was analyzed by Mr. Chenevix in the following manner; One hundred parts of it were boiled with potash till the arsenic acid was separated. Nitrate of lead was mixed with the solution; 100 parts of the precipitate indicated 33 of arsenic acid. That portion of the ore which eluded the action of the potash was treated with muriatic acid; the undissolved residuum was silex. The muriatic acid was super-saturated with ammonia. The iron precipitated; but the copper was dissolved by the ammonia.*

* Phil. Trans. 1801, p. 219.

LEAD.

PART XXXIX.

SECT. I.

NATURAL HISTORY OF LEAD.

THIS metal is found in considerable quantity in many parts of the earth. It exists in nature in different forms, seldom if at all in the metallic state. It is found in the state of an oxyd, forming the *red lead ore*, mixed with a portion of iron, clay, and other earths.

The colour of this mineral is aurora red, resembling red arsenic. It is found in small lumps of an indeterminate figure, and also crystallized in four-sided rhomboidal prisms.

Combined with carbonic acid it constitutes the *sparry lead ore*, so called because it has the texture and crystallization of certain spars. There are a great many varieties of this kind. It is found united with sulphuric acid, phosphoric, arsenic, molybdic, and chromic acids. Lastly, lead exists mineralized by sulphur forming what is called *galena (sulphuret of lead)* which is by far its most abundant ore. This ore, which is very common, is found both in masses and crystals.

The primitive form of its crystals is a cube. Its colour is of a bluish lead gray. It has a considerable metallic lustre; its texture is foliated. It stains the fingers, and often feels greasy. It contains frequently a minute quantity of silver.

PROPERTIES OF LEAD.

Lead is of a bluish white colour when fresh cut. It is malleable. It soon tarnishes in the atmosphere. It may easily be cut with a knife, and stains the fingers bluish gray when rubbed. It fuses at 540° Fahr.* and renders other more refractory metals fusible. It becomes vitrified in a strong and continued heat, and vitrifies various other metals. It is the least elastic of all the metals. It is very laminable, but it possesses very little ductility. Its specific gravity is from 11.352 to 11.435. It crystallizes by cooling in small octahedra. When fused in contact with air, its surface first becomes yellow and then red. It unites by fusion with phosphorus and sulphur. The greater part of the acids act upon it. The sulphuric acid requires the assistance of a boiling heat. Nitric acid is decomposed by it. Muriatic acid acts very weakly on it. Acetic acid dissolves it. Fluoric acid attacks it by heat, and slightly in the cold. It unites with other metals, but few of its alloys are applied to any use. When combined with mercury it forms a crystallizable alloy which becomes fluid when triturated with that of bismuth.†

METHOD OF OBTAINING LEAD.

In order to obtain lead in the large way, the ore is picked from among the extraneous matter with which it was combined by nature. It is then pulverized and washed. It is next roasted in a reverberatory furnace in which it is to be agitated, in order to bring all its surfaces in contact with the air. When the external parts begin to soften, or assume the form of a paste, it is covered with charcoal, the mixture is stirred, and the heat increased gradually; the lead then runs on all sides, and is collected at the bottom of the furnace, which is perforated so as to permit the metal to flow into a receptacle defended by a lining of charcoal dust.

The scoriæ remaining above in the furnace still retain a considerable portion of lead; in order to extract it they are fused in a blast furnace. The lead is by that means separated, and cast into iron moulds, each of which contains a portion called *a pig of lead.* These pigs are sold under the name of *ore lead.*

* According to Davy 612° Fahr.

† A wire $\frac{1}{75}$.6 of an inch diameter, supports only 18.4 lbs. DAVY.

To disengage the silver from lead thus obtained, the metal is subjected to the action of the refining furnace. The continual application of a quantity of fresh air which is thrown by means of large bellows upon the fused lead, which is at the same time heated as intensely as possible, oxydizes the lead, and converts it into the yellow scaly oxyd, known by the name of *litharge*, or vitreous oxyd of lead.

This oxyd being driven off from the surface of the fused metal, as it is formed, leaves the silver alone unaltered at the bottom in a metallic state.

The litharge is then to be fused in contact with charcoal, in order to reduce it again to the state of metallic lead.

To obtain perfectly pure lead, the lead of commerce may be dissolved in nitric acid, and the solution be decomposed by adding to it, gradually, a solution of sulphate of soda, or sulphuric acid, so long as a precipitate ensues. This precipitate must be collected on a filter, washed repeatedly in distilled water, and then dried. In order to reduce it to the metallic state, let it be mixed with two or three times its weight of black flux, introduce the mixture into a crucible, and expose it briskly to a red heat.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF LEAD.

EXPERIMENT I.

*Lead unites to oxygen in different proportions.**

PUT into an iron ladle any quantity of lead, and place it over the fire; as soon as the metal is fused, it becomes oxydated at the surface; a gray pellicle is formed, which, on being removed, is soon succeeded by another, and in this manner the whole of the lead may be converted into a dirty gray powder, which is *gray oxyd of lead.*

If the oxyd obtained in the above process be exposed to a low red heat, it acquires a pale yellow colour. This is what is called *common massicot.* By continuing the

* There appear to be four oxyds of lead; the yellowish gray, or common massicot, is the protoxyd: the yellow massicot is the deutoxyd: the red lead is the tritoxyd: the puce (flea) coloured minium is the tetroxyd and probably the per oxyd. See Davy. Massicot will contain about 10, red minium 15, and brown minium 20 per cent. of oxygen. T. C.

oxydation, the oxyd assumes a dark yellow colour, and in that state is called *yellow oxyd of lead*, formerly *yellow massicot*.

If the yellow oxyd obtained as above be exposed to a still stronger heat in a reverberating furnace, not capable of bringing it to a state of fusion, it acquires a beautiful red colour. This is *red oxyd of lead*, or *minium*.

By exposing the red oxyd of lead to a heat capable of reducing it to a state of semi-vitrification, its parts become agglutinated into small thin scales, which always preserve their red colour, but have less brightness. The oxyd now is called *semi-vitreous oxyd of lead*, or *litharge*.*

If the red or semi-vitreous oxyd of lead be exposed to heat in a crucible, and the fire raised by degrees, it enters into fusion, but with much more difficulty than lead, and becomes converted into glass: this glass, however, has so much action on earthy substances, that it penetrates the common crucibles, and makes them enter into fusion.

This inconvenience may be obviated by mixing one part of sand with three of the red oxyd; put this mixture into a good crucible, place it under the muffle of a furnace, and keep it at a white heat for two or three hours, or until the matter be fused. By this means *glass of lead* will be obtained, approaching in colour to amber. This vitreous oxyd of lead constitutes the basis of the glazing for common pottery.

Experiment II.

The oxyds of lead decompose muriate of soda and muriate of ammonia.

Mix two parts of fine powdered red oxyd of lead with one of common salt in a stone mortar, and form the two substances into a paste, with a little water, adding more occasionally as the mixture becomes dry.

The soda of the common salt becomes disengaged, and the muriatic acid unites with the oxyd of lead. Wash off the soda, dry the white mass, and fuse it in a crucible, it will form the beautiful and durable pigment called *patent* or *mineral yellow*.

* Litharge is also obtained in the process of refining lead for silver. A current of air over the surface of the melted metal, converts the lead into an oxyd called litharge. T. C.

The decomposition of muriate of ammonia by oxyd of lead may be effected in a similar manner when assisted by caloric.

Experiment III.

Lead combines with sulphur by fusion.

Fuse three parts of lead in an iron ladle; add one part of powdered sulphur, and stir the mixture; the sulphur will speedily combine with the lead, and form a black and somewhat scaly powder. This matter does not enter into fusion until it has been brought to a red heat; it then forms a black brittle mass, disposed in facets, much less fusible than lead. This is *sulphuret of lead*, or *artificial galena*.

Experiment IV.

Lead unites with phosphorus by fusion.

If a mixture of equal parts of filings of lead and glacial acid of phosphorus be fused in a crucible, with one-eighth part of powdered charcoal, a button will be obtained, which differs very little in appearance from lead. It is malleable, but separates into thin plates when hammered, and may be easily cut with a knife. It loses its brilliancy much sooner than lead; and when fused by the blow-pipe on charcoal, the phosphorus burns and abandons the lead.

Phosphuret of lead may also be formed by dropping pieces of phosphorus into melted lead, and covering the crucible as expeditiously as possible.*

Experiment V.

Lead and tin form an alloy which is more fusible than either of the metals separate.

This alloy, which is known by the name of plumbers solder, is made by fusing together, in an iron ladle, two parts of lead and one of tin.

* There are no combinations yet made of lead with hydrogen, azot, or carbon. Davy.

White lead and litharge according to Thompson and Davy appear to be deutoxyds combined with carbonic acid: but the litharge of a silver refinery must be an oxyd: whether different from yellow massicot is not known. T. C.

Experiment VI.

Lead precipitates silver or mercury.

Suspend a piece of lead, scraped bright, in a concentrated solution of nitrate of silver, or nitrate of mercury. The lead, by its greater affinity for oxygen, will first become black, and then separate the silver or mercury from the solution.

A similar effect will take place by distilling muriate of mercury with granulated lead. Mercury will pass over into the receiver, and muriate of lead remain in the retort.

Experiment VII.

Zinc precipitates lead in a metallic state.
(Lead tree.)

Dissolve one part of acetite of lead in thirty-six or forty of distilled water; put this solution into a glass bottle, suspend a cylinder or ball of zinc in it, and then leave the vessel containing it undisturbed. The zinc will soon become covered with a moss-like substance, which increases gradually, shooting out symmetrical leaves of a metallic splendour, which arrange themselves into a kind of tree.

Rationale....The explanation of this experiment is obvious; the zinc has a greater affinity for oxygen than the lead has, it therefore deprives the latter of it, which being thus reduced to the metallic state, arranges itself by virtue of its molecular attraction into a symmetrical form.

ANALYSIS OF ORES OF LEAD.

In order to assay lead ores, different ways are made use of, according to the nature or composition of those ores. When in the state of an oxyd, or combined with oxygen *(red lead ore)* it may be dissolved in nitric acid, and precipitated from it in the metallic state by zinc. If the ore contains silver, the solution is to be much diluted

with distilled water, and the silver separated by muriatic acid; after which the lead may be precipitated either by zinc or an alkali.

Or, the oxyd may be merely fused with charcoal, which separates the oxygen and sets the lead free.

Argentiferous antimoniated lead ore was thus analysed by Klaproth: It was digested with seven times its weight of nitric acid, by which part was dissolved. The residuum was treated repeatedly with muriatic acid, which was poured off while boiling hot. What remained undissolved was sulphur, mixed with a little silex. Common salt being added to the nitric solution, two precipitates appeared: 1. A heavy flaky one, which was muriate of silver: 2. Acicular crystals of muriate of lead. These crystals were dissolved in water, and the solution added to the nitric solution. From this solution sulphate of soda precipitated a heavy white powder, which was sulphate of lead. Lastly, ammonia afforded a precipitate, which was a mixture of iron and alumine. The muriatic solution being concentrated, crystals of muriate of lead appeared; the concentration was continued as long as any crystals formed. The residuum being diluted with water, gave a white precipitate, which was oxyd of antimony.

The *sparry lead* ore, or carbonate of lead, may be analysed in the following manner: Let one part of the ore, reduced to powder, be dissolved in ten parts of nitric acid, and boil down the solution to one-third. The iron and antimony, if any be present, will be separated, and may be estimated by dissolving the precipitate in muriatic acid. If water be added to this solution, the antimony which was present will be separated, and on adding ammonia the iron becomes disengaged. In order to ascertain the quantity of lead which was contained in the ore, the nitric solution must be precipitated by the addition of sulphuric acid. The precipitate, after being washed, must be dried and weighed; after deducting 70 per cent. the remainder shews the quantity of lead it contains.

Phosphate of lead may be dissolved in boiling muriatic acid. The solution is to be diluted with waster till the crystals of muriate of lead are dissolved: being then saturated with ammonia, the lead and iron are precipitated. Dissolve the precipitate in muriatic acid, evapo-

rate to dryness, and treat the dry mass with alcohol. The muriate of iron is dissolved; but the muriate of lead remains. Finally, drop lime water into the ammoniacal solution as long as any precipitate appears. That precipitate indicates the proportion of phosphoric acid.

Arseniate of lead has not been analysed. It might be treated with an alkali, which would separate the lead. This metallic precipitate is then to be re-dissolved in nitric acid, and analysed by the methods above described. The alkaline arseniate may be dissolved in water, and treated with nitrate of lead; 100 parts of the dry precipitate will indicate 33 of lead.

The sulphurated lead ores, or *galenas*, may likewise be analysed by first depriving them of the sulphur by torrefaction, and afterwards fusing them with two parts of black flux and half a part of iron filings, in a covered crucible, for half an hour: by this means the iron takes up the remaining sulphur; the alkali of the flux promotes the fusion, while its carbon carries off the oxygen; and thus the metal is recovered.

In order to obtain pure lead, let the lead of commerce be dissolved in nitric acid, and precipitate it by means of sulphate of soda. The precipitate, which is a sulphate of lead, after being washed, may be reduced in a crucible, by fusing it with three times its weight of black flux.

TIN.

PART XL.

SECT. I.

NATURAL HISTORY OF TIN.

IT has been much doubted whether tin is ever found native. In the opinion of Kirwan there are sufficient authorities to determine the question in the affirmative. The *native oxyd of tin* or *tin stone*, occurs both massive and crystallized. Its colour is a dark brown, sometimes yellowish gray. When crystallized it is somewhat transparent. The *wood tin ore* is a variety of the native oxyd, termed so from its fibrous texture. This variety has hitherto been found only in Cornwall. It occurs in fragments which are generally round, and its colour is brown, sometimes inclining to yellow. Tin is also found mineralized by sulphur, associated always with a portion of copper, and often of iron. This ore is called *tin pyrites*. Its colour is yellowish gray. It has a metallic lustre, and a fibrous, or lamellated texture; sometimes it exhibits prismatic colours. Tin is comparatively a rare metal, as it is not found in great quantity any where but in Cornwall or Devonshire; though it is likewise met with in the mines of Bohemia, Saxony, the island of Banca, the peninsula of Malacca, and in the East Indies.*

PROPERTIES OF TIN.

Tin is of a brilliant white colour, though not quite so white as silver. It is one of the lightest of the metals;

* The Cassiterides were so called by the ancients from the tin found there, celtic tin; Κασσιτερον Κελτικον.

its specific gravity when hammered, being 7.299. It is very fusible, melting at about 410° Fahr.* By intense heat it is volatilized. It becomes oxydated by a moderate degree of heat. It easily bends and emits a noise, called the crackling of tin. It is exceedingly soft and ductile. It may be reduced to very thin leaves. *Tin foil*, or tin leaf, which is tin beat out, is about $\frac{1}{1000}$ part of an inch thick. It has scarcely any sound. It resists the action of the air. It crystallizes in rhombs formed of small octahedra. It unites, by fusion, with phosphorus and sulphur. It does not decompose water alone, or in the cold; but easily by means of many other bodies. It decomposes sulphuric acid, and unites with the sulphureous acid. It decomposes the nitric acid, and is very soluble in muriatic acid. Nitro-muriatic acid acts on it very readily. It is slightly soluble in the fluoric and boracic acids. Phosphoric acid attacks it by heat. Tartareous acid has no perceptible action on it. The oxalic and acetic acids dissolve it in small quantities. The alkalies appear to have some action on it by heat. It combines with sulphuret of potash by fusion. It unites with the greater number of the metals with facility. It decomposes muriate of mercury, and muriate of ammonia. It causes nitrate of potash to detonate. It takes fire spontaneously in oxygenated muriatic acid gas, and is capable of combining with two different proportions of oxygen.

METHOD OF OBTAINING TIN.†

In order to obtain tin from its ore, a mere fusion of it, with pounded charcoal, is sufficient. Or, a certain quantity of the ore is first freed from sulphur by torrefaction; after which it is mixed with equal parts of potash, one half of common resin, and two parts of black flux: the mixture is then fused in a crucible covered with charcoal, by means of which the metal is recovered in its metallic state. In order to obtain pure tin, let the tin obtained before be rapidly dissolved in strong nitric acid with heat. Thus some of the metals it may contain will be held in solution, and others become oxydated; but muriatic, or nitro-muriatic

* At 442° Fahr. DAVY.

† To obtain pure tin, dissolve it with heat in pure nitric acid. Wash the white powder: heat it for half an hour in a covered crucible with $\frac{1}{4}$th its weight of charcoal. DAVY.

acid will, on digestion, take up these oxyds, and after sufficient ablution leave that of tin, which may afterwards be reduced by mixing it when pulverized with double its weight of a flux formed of equal parts of pitch and borax, or resin and borax, and putting it into a covered crucible, lined with charcoal, which must be placed in a forge, and strongly heated for a quarter of an hour.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF TIN.

Experiment I.

*Tin unites to oxygen in different proportions.**

LET this metal be melted in an iron ladle in contact with air; its surface will become covered with a gray pellicle, which forms wrinkles; when this is taken off, it is soon succeeded by another, and in this manner the whole metal may be converted into a powder, which is *yellow* or *gray oxyd of tin.* To free it from the particles of tin which are not oxydated, it must be passed through a sieve of lawn or silk. It is extremely difficult to separate it entirely from the tin, it therefore is of a gray colour.

Let the oxyd of tin, obtained in the above process, be exposed to a red heat in a crucible, or an earthen capsule under a muffle for some time, stirring it occasionally with an iron rod, and it will become more oxydated, and acquire a white colour. This is *white oxyd of tin*, commonly called *putty of tin.* It is used for polishing glass specula for telescopes, marble, steel, &c. It deprives every kind of glass of its transparency, and converts it into *white enamel.*

The *yellow oxyd of tin* may also be obtained by dissolving tin filings in diluted nitric acid, without the assistance of heat, and then precipitating the solution by pota[illegible]

The *white oxyd of tin* may be obtained by hea[illegible] in concentrated nitric acid; a violent effervescence e[illegible]es, and the whole of the tin is converted into a white powder, which is deposited at the bottom of the vessel.

* Davy says there are but two oxyds of tin, the gray and the white: the first containing 13.5, the last 24 per cent. of oxygen.

Experiment II.

*White oxyd of tin combines with sulphur by fusion, and forms yellow sulphurated oxyd of tin (aurum musivum.)**

The process generally adhered to in this preparation is as follows: Twelve parts of tin are melted in a crucible by a brisk fire, and three of mercury added to it. This mass is to be reduced to powder in a stone mortar, and then intimately mixed by trituration with seven parts of sulphur, and three of muriate of ammonia: the mixture is exposed to heat as long as any white vapours are disengaged; the heat is then moderately increased; a little sulphuret of mercury and some oxygenated muriate of tin sublime, and the *aurum musivum* remains at the bottom of the matrass.

A variation in the proportion of the ingredients produces no very essential change in the result. Pelletier obtained a very beautiful musive gold by distilling together equal parts of mercury, muriate of ammonia, tin, and sulphur. The main point is the proper regulation of the heat; if this be too strong the operation does not succeed, and instead of a beautiful *aurum musivum*, common sulphuret of tin, of a very dark colour, is obtained.

Rationale.—The theory of the formation of this compound is one of the most intricate in chemistry, but it appears to have been sufficiently ascertained by the researches of Pelletier. In the first amalgamation and trituration of the mercury and tin, the latter is divided, and in some degree oxydated: when the mixture of this amalgam with the sulphur and muriate of ammonia is heated, the muriatic acid, by a disposing affinity, enables the tin to be oxydated by decomposing the water, and this oxyd combines with the muriatic acid; the hydrogen of the water is disengaged with the ammonia of the muriate of ammonia; this ammonia unites with a portion of the sulphur, and forms sulphuret of ammonia, which being disengaged, causes the white fumes. The heat being now augmented, the muriate of tin is again decomposed, the oxyd of the metal attracting a portion of

* There are two sulphurets of tin, the common and the super-sulphuret or aurum musivum, which is made from the white or per oxyd. Davy.

the sulphur, and forming the *aurum musivum*. Such is the aetiology of that complicated process given by Pelletier.

Aurum Musivum is employed to give a beautiful colour to bronze, and to excite the strength of electrical machines. It is used by japanners, and for many articles intended to have the appearance of metallic gold.

Experiment III.

Tin decomposes nitric acid with great rapidity, and forms ammonia by the addition of an alkali.

Moisten some powdered tin with concentrated nitric acid, and when the red fumes have ceased to arise, add some solution of potash. A strong smell of ammonia will be immediately produced.

Rationale....In this case the tin decomposes both the nitric acid and the water: the hydrogen of the latter and the nitrogen of the former being presented to each other in their nascent state, by the addition of the alkali, unite and form ammonia, which is disengaged.

Experiment IV.

Tin combines very readily with sulphur.

This sulphuret may be obtained by fusing together, in a covered crucible, one part of tin with four or five of sulphur. The compound is heavier than tin, and not so fusible.

Experiment V.

Tin combines also with phosphorus.

Take equal parts of tin filings and glacial acid of phosphorus, and one-eighth part of charcoal-powder: mix these three substances intimately, and fuse them in a crucible; a few grains of a metallic appearance, and of a pretty large size, will be obtained. These do not differ in appearance from tin, but when melted by the blow-pipe, the phosphorus abandons the metal and burns on its surface.*

* It contains 17 per cent. phosphorus: it may be cut with a knife. Tin does not combine with hydrogen, azot or carbon. Davy.

REMARK.....In fusing tin with charcoal-powder and glacial acid of phosphorus, care must be taken to regulate the fire properly, for the phosphorus easily abandons the metal.

EXPERIMENT VI.

Tin is soluble in sulphuric acid.

Put into a matrass five parts of concentrated sulphuric acid and one part of tin in grains; place the vessel on a sand-bath, and the tin will dissolve without any effervescence; sulphureous acid will be disengaged, and sulphur will be formed, which remains liquid at the surface of the solution while warm, but precipitates when it cools.

This solution is of a dark-brown colour when first prepared, but becomes transparent by rest.

If it be long exposed to heat, the tin is precipitated in the form of a white oxyd.

This solution furnishes crystals in fine needles interwoven with each other, called *sulphate of tin.*

EXPERIMENT VII.

Tin is soluble in muriatic acid.

Put one part of tin into a matrass, pour over it two of concentrated muriatic acid, and place the vessel on a sand-bath; hydrogen gas will be evolved, and a solution of a light amber colour will remain in the matrass.

If the solution be evaporated, brilliant and very regular crystals will be obbained, which are *muriate of tin.*

EXPERIMENT VIII.

Tin is soluble in nitro-muriatic acid.

Put two parts of nitro-muriatic acid into a Florence flask, add gradually one part of tin; if the heat be too great, the vessel must be plunged into cold water to diminish it. This solution is of a reddish brown colour, and often forms in a few moments a viscous trembling

jelly. If the solution be diluted with about half its weight of water, it becomes concrete, and is of an opal colour.

Experiment IX.

Tin decomposes muriate of ammonia.

Take equal parts of granulated tin and muriate of ammonia, introduce the mixture into a retort, and adapt to it a receiver in the mercurial pneumatic trough. As soon as the retort is heated, a decomposition takes place, the ammonia is disengaged in the form of gas, and the residuum is a *solid muriate of tin*, decomposable by water.

Experiment X.

Tin decomposes muriate of mercury.

In order to obtain this combination, which was formerly known by the name of *Libavius's smoking liquor*, fuse in an iron spoon five parts of tin, and one of mercury, and triturate the mixture in a marble mortar, with an equal quantity of oxygenated muriate of mercury. Put the mixture into a glass retort, and adapt to the neck of it a middle-sized receiver; place the retort on a sand-bath, and proceed to distillation.

A colourless fluid will first pass over; a thick white vapour will then burst out with a kind of explosion, and cover the sides of the receiver. This vapour is condensed into a transparent liquor, which exhales thick, white, and very abundant fumes: this is the *oxygenated muriate of tin.*

Remark.....Adet has published a very interesting memoir on this production. From the observations of this chemist it appears, 1st, That the oxygenated muriate of tin is a saline substance, formed by the combination of tin with oxygenated muriatic acid deprived of water. 2d, That if it be mixed with water in the proportion of seven to twenty-two, a concrete saline substance will be obtained. 3d, That when diluted with water, it can dissolve a new quantity of tin without a disengagement of hydrogen gas. According to these facts, it is a true *oxygenated muriate of tin.*

Experiment XI.

Tin is soluble in liquid potash, soda, &c.

If a very concentrated solution of potash, or soda, be mixed with tin filings, or tin foil, and boiled, part of the metal will be dissolved; for on adding an acid the solution will be decomposed, and the tin be precipitated.

Experiment XII.

Tin causes nitrate of potash to detonate.

For this purpose fuse tin in a crucible, and heat it to redness; then project over it pounded nitrate of potash exceedingly dry; a deflagration will take place, and a brilliant white flame will arise. Add a new quantity of nitrate of potash till no more denotation ensues; remove the crucible from the fire, and having separated the contents from it, wash them in water, filter the liquor which contains the potash of the nitrate, and the remainder on the filter will be oxyd of tin, mixed with a little alkali rendered caustic by the tin. Care, therefore must be taken to wash it well; and a small quantity of acid may be added, in order to precipitate the oxyd of tin.

Experiment XIII.

Tin detonates with oxygenated muriate of potash by percussion.

If a few grains of finely divided tin be mixed with double the quantity of oxygenated muriate of potash, a compound will be formed which detonates loudly by percussion.

Experiment XIV.

Accension of tin-foil by nitrate of copper.

Spread thinly on a piece of tin-foil, three or four inches square, some dry nitrate of copper, and wrap it up. No effect will follow. Unfold the tin-foil, and sprinkle the nitrate of copper with a very little water; wrap it up again as quickly as possible, pressing down the edges closely. Considerable heat attended with fumes will now be ex-

cited; and if the experiment has been dexterously managed, even light will be evolved. This shows that nitrate of copper has no action on tin till in a state of solution.

REMARK....This is a common experiment, shown by teachers of chemistry, to prove that bodies do not act on each other in a dry state. But there seems to be an error with regard to the action of nitric acid on tin; for nitric acid, freed as much as possible from water, will not act upon tin at all; the action only takes place when the acid is diluted. Hence the rationale of this experiment must be sought for in the action of the water on the nitric acid of the nitrate of copper.

EXPERIMENT XV.

Tinning copper vessels.

Vessels of copper, especially when used as kitchen utensils, are usually covered with a thin coat of tin, to prevent the copper from oxydating, and to preserve the food which is prepared in them from being mixed with any of that poisonous metal. These vessels are then said to be *tinned.* Their interior surface is scraped very clean with an iron instrument, and rubbed over with muriate of ammonia. The vessel is then heated, and a little pitch thrown into it, and allowed to spread on the surface. Then a bit of tin is applied all over the hot copper, which instantly assumes a silvery whiteness. The intention of the previous steps of the process is to have the surface of the copper perfectly pure and metallic; for tin will not combine with the oxyd of copper. The coat of tin thus applied is exceedingly thin. Bayen ascertained, that a pan nine inches in diameter, and three inches three lines in depth, when tinned, only acquired an additional weight of 21 grains. Nor is there any method of making the coat thicker. More tin indeed may be applied; but a moderate heat melts it, and causes it to run off.*

* Proust has ascertained that if the tin be alloyed with one part out of three of lead, it is equally good for tinning vessels with pure tin.

A pan 9 inches in diameter, and 3¼ inches deep gains but 21 grains according to Bayen on being tinned. T. C.

Experiment XVI.

Tinning iron.

Iron is tinned in the following manner: Plates of iron, after being reduced to a proper thickness, are immersed in water acidulated with sulpuric or muriatic acid, in order to clean them completely from rust; they are then scoured quite bright, and placed in a pot, or other convenient vessel, filled with melted tin, whose surface is covered with suet, pitch, or resin, to prevent the surface of the tin being oxydated. The plates of iron being then suffered to pass through it, the tin will unite with them so as to cover each side of the plate with a thin white coat. They are then what are called tin-plates.

In the same way stirrups, buckles, bridle-bits, &c. are covered with coats of tin.

Experiment XVII.

Silvering looking glasses.

Looking glasses are covered on one side with an amalgam of tin and mercury. For that purpose tin-foil is evenly placed on a flat stone, or table; and quick-silver, in which some tin already has been dissolved, is poured upon it, and spread with a feather or bunch of cloth, until its union has brightly lined every part. A plate of glass is then cautiously slid upon it from one end to the other, in such a manner that part of the redundant mercury is driven off, or swept away, before its edge. The remainder is now united to the tin. The glass is then loaded with weights all over, so as to press out still more of the mercury; by inclining now the table this remaining quantity of the superfluous mercury becomes discharged, and in a few hours the rest of the tin-foil and mercury adheres so firmly to the glass, that the weights may be removed without any danger of its falling off.

In the small way about two ounces of mercury are requisite for covering three square feet of glass.

ANALYSIS OF ORES OF TIN.

In order to analyse the ore called *tin-stone*, let one part of it be pulverized and digested with six of concentrated

sulphuric acid, for at least six hours. Then decant the fluid, dilute it with water, and filter it. The residue consists of silex. Having done this, add to the solution dissolved potash as long as a precipitate ensues. Then collect the precipitate by transferring the whole on a filter, wash it repeatedly, and when dry, reduce it, by fusing it with half its weight or less of charcoal powder. If the iron which it contained is wished to be separated, it may be precipitated from the solution in sulphuric acid, by the addition of triple prussiate of potash.

The ore may be analyzed in the dry way in the following manner: Let one part of the ore be fused with six of potash, and dissolve the mass in a sufficient quantity of water. The insoluble residue must be several times fused with a like quantity of potash, and dissolved in water. The residue, if any, may then be dissolved in muriatic acid by heat. The alkaline solutions must be mingled together, and decomposed by adding to them a solution of carbonate of soda. The obtained precipitate must then be dissolved in muriatic acid, and mixed with the solution in muriatic acid obtained before. If plates of zinc be now immersed in the solution, the tin will be precipitated. The iron may be separated from the solution, if deemed necessary, by a solution of triple prussiate of potash.

[Tin 2 parts, zinc 1 part, is Chinese tutenag according to Wallerius: Keir, says it is copper, zinc and iron.

Copper with $\frac{1}{8}$ to $\frac{1}{12}$ tin, forms bronze.

Composition for telescopes: 32 parts copper: 15 parts tin: 1 part brass: 1 silver: 1 arsenic. DAVY.

The gong of the Chinese seems to me to be copper, tin, and nickel. T. C.]

ZINC.

PART XLI.

SECT. I.

NATURAL HISTORY OF ZINC.

ZINC is found in nature combined with oxygen, carbonic acid, and sulphuric acid; and mineralized by sulphur. Native oxyd of zinc is commonly called *calamine*. It occurs in a loose and in a compact form, amorphous, of a white, gray, yellow, or brown colour, without lustre or transparency. Combined with carbonic acid, it is called *vitreous zinc ore*, or *native carbonate of zinc*. It is found in solid masses, sometimes in six-sided compressed prisms, both ends being covered with pentagons. Its colour is generally grayish inclining to black. It is often transparent. *Sulphate of zinc* is found efflorescent in the form of stalactites, or in rhombs. *Sulphuret of zinc*, or *blende*, is the most abundant ore. It is found in various colours; brown, yellow, hyacinth, black, &c. and with various degrees of lustre and transparency. The zinc ore is contaminated with iron, lead, argillaceous and siliceous earths, &c. It occurs both in amorphous masses and crystallized in a diversity of polygonal figures.*

PROPERTIES OF ZINC.

Zinc on its fracture appears of a shining white colour, with a bluish tint. It possesses a considerable degree of ductility, and may be extended when heated to a certain degree between metallic cylinders in a flatting mill. Its

* To procure it pure, precipitate a solution of white vitriol (sulphate of zinc) with a rod of zinc. Then precipitate the pure solution of zinc, with a solution of pearlash. Wash the powder: mix with $\frac{1}{4}$th charcoal powder, and expose to a red heat in a covered crucible for half an hour. DAVY.

specific gravity is 7. 190. It melts at 700° Fahr.* By a further increase of heat it is volatilized without change. When melted in contact with the air, its surface becomes covered with an imperfect oxyd; when heated a little above ignition, it burns with a bright yellowish white flame, slightly tinged with green, and a white oxyd is formed in light flakes, which are carried off by the rapid current of air in the burning metal. It undergoes very little alteration from the air; its surface becomes slightly tarnished. It is not acted on by water at the usual temperature of our atmosphere; but at that of ignition, it decomposes this fluid rapidly. It is oxydated and dissolved by the greater number of the acids. It has a very strong attraction for oxygen, and therefore precipitates the greater number of the metals from their solutions. All the alcalis when digested or boiled with zinc, blacken its surface, and dissolve a minute portion of it. It decomposes muriate of ammonia, sulphate of potash, and various other neutral salts. A mixture of nitrate of potash and zinc detonates with rapidity. Sulphur and zinc cannot be united by fusion. Gold, silver, platina, and nickel, form brittle compounds with zinc. It easily unites with mercury and tin. It does not combine with lead or bismuth. The most frequent and at the same time most useful combination of zinc is that with copper. It unites with great difficulty to arsenic, iron and cobalt. It inflames in oxygenated muriatic acid gas, and fulminates by pressure or a blow with oxygenated muriate of potash. It is a very strong conductor of galvanism.

METHOD OF OBTAINING ZINC.

In order to obtain zinc from its ores, they must first be torrefied, and then mixt with half their weight of charcoal powder, and distilled in an earthen retort three quarters full, and to which a receiver is luted, in a strong heat gradually increased for some hours. The zinc in its metallic form is then found in the neck of the retort. In order to obtain the metal in a pure state, dissolve it in diluted sulphuric acid, and boil the concentrated solution

* 680° Fahr. DAVY.
It is malleable and ductile between 280° and 400° of Fahr. T. C.
A wire $\frac{1}{10}$ of an inch supports 26 lb. Muschenbroeck.

for a few minutes upon granulated zinc. Then filter it, and precipitate it by soda. Collect the precipitate, wash it, and when dry mix it with half its weight of charcoal-powder, and submit it to a red heat in an earthen retort. Pure zinc will then be found in the neck of the retort.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF ZINC.*

Experiment I.

Zinc when exposed to a strong heat burns with a bright flame, and is volatilized.

PLACE a large crucible on two bricks, in a good furnace; incline it, at an angle of 45°, and form before its aperture a rest to support the cover, in order that the crucible may be shut when necessary.

Put zinc into the crucible, and fuse it by keeping the crucible shut. When of a red heat, uncover it, and a very bright white flame will rise from the surface of the zinc, flakes of exceedingly white and light matter, like cotton, will rise at the same time; this is *white oxyd of zinc.* Remove the oxyd with a long-handled iron spoon, and more oxyd will be immediately formed, which must be removed in like manner. This operation is to be continued till the whole of the zinc is converted into an oxyd.

Experiment II.

Zinc unites with phosphorus by fusion.

Put into an earthen retort two parts of filings of zinc and one of phosphorus, and having adapted a receiver to the neck of the retort, proceed to distillation.

The product will be a little phosphorus in the receiver; the neck of the retort will contain, 1. zinc in a metallic form; 2. a sublimation of a red efflorescence; 3. white oxyd of zinc; 4. a sublimation in needles, having a metallic ap-

* It combines in one proportion with oxygen which exists to the amount of 18 per cent. therein. This is the white oxyd, flowers of zinc, nihil album, white sublimate of zinc. Davy.

Zinc unites with sulphur, when sulphur in vapour is passed over melted zinc. T. C.

It has not been combined with hydrogen or azot. T. C.

pearance, with a slight tint of blue, and prismatic. Or, A phosphuret of zinc may be obtained by projecting small pieces of phosphorus well dried, upon zinc broken also into small pieces, and brought to a red heat in a crucible. As the zinc enters into fusion project the phosphorus, and at the same time small bits of resin, to prevent the oxydation of the zinc. When the crucible is taken from the fire its contents will be a metallic substance, which is phosphuret of zinc.

Experiment III.

Zinc decomposes nitric acid readily.

Put granulated zinc into a Florence flask, and pour over it weak nitric acid: a strong effervescence will take place, and nitrous gas becomes disengaged in a large quantity.

The solution of nitrate of zinc has a yellow colour, and when newly made is somewhat turbid, but becomes gradually transparent.

By evaporation it furnishes crystals in tetrahedral prisms, terminated by pyramids of four faces, which are striated and attract moisture from the air.

Experiment IV.

Zinc detonates rapidly with nitrate of potash.

Mix equal parts of nitrate of potash and filings of zinc, and project the mixture by spoonfuls into a crucible which has been brought to a state of ignition. When the powder has acquired a certain degree of heat, a strong detonation suddenly takes place; as soon as it ceases throw another spoonful of the mixture into the vessel, and repeat the operation till the whole quantity is consumed. The residuum will be an oxyd of zinc.

Remark....This experiment requires caution, to prevent accidents.

Experiment V.

Zinc detonates by percussion with oxygenated muriate of potash.

When a few grains of fine zinc filings and oxygenated muriate of potash are struck on an anvil, a violent detonation takes place, with a white flame.*

Experiment VI.

Zinc decomposes muriate of mercury.

Distil two parts of muriate of mercury and one of zinc, in a glass retort: a salt which crystallizes in small needles united together will be sublimed, and the mercury will remain fluid in the retort. This salt is muriate of zinc.

ANALYSIS OF ORES OF ZINC.

For extracting zinc from the ore called *blende*, let one part of the powdered ore be gently boiled in six of diluted nitric acid in a flask to dryness, and repeat this operation with the same ore two or three times. Then dissolve the dry mass in a sufficient quantity of water to which about one-fourth of nitric acid has been added, and precipitate the fluid by a solution of soda. Collect the precipitate on a filter, wash it by passing water over it, and re-dissolve it in muriatic acid. Then decompose this solution by liquid ammonia in excess, in order to separate the iron, lead, and alumine which may have been dissolved. If this precipitate be boiled in four times its quantity of potash, the alumine will be separated.

From the before-going solution the zinc may be separated by the addition of an acid. It may be reduced to the metallic state by strongly igniting it with half its weight of charcoal in a closed crucible.

In order to analyse *calamine*, let it be digested repeatedly in diluted nitric acid, and the insoluble residue be boiled in concentrated muriatic acid three times. What remains after ablution with boiling water is silex.

The nitric solution obtained before contains the zinc, and also iron and alumine, if they were present in the ore.

* It takes fire when its filings are poured into chlorine or oxymuriatic gas. Davy.

Let therefore the solution be evaporated to dryness, redissolve it in nitric acid, and evaporate it again as before, in order to render the iron as insoluble as possible. Then dissolve the mass in water.

A tolerably exact assay of the ore called calamine, may be made in the following manner:

Mix any quantity of the pulverized ore, previously freed from sulphur by roasting, with one-eighth part of charcoal-powder. Put this mixture into a crucible capable of containing thrice the quantity. Diffuse equally amongst this mixture a quantity of small grains or thin plates of copper equal to that of the calamine or ore employed, and upon the whole lay another equal quantity of grains or plates of copper, and lastly cover this latter portion with charcoal powder. Lute a cover upon the crucible, and apply a red heat during one or two hours. The volatilized zinc will thus combine with the copper and convert it into brass. By comparing the weight of the metal after the operation with the weight of the copper employed, the quantity of zinc united with the copper will be known.

The copper which has not been converted into brass, or more copper with fresh charcoal powder, may be again added in the same manner to the remaining ore, and the operation repeated with a heat somewhat more intense, in order that any zinc remaining in the ore may be thus extracted. A curious circumstance is, that a much greater heat is required to obtain zinc from its ore without the interposition of copper, than in the process now described of making brass; in which the separation of the zinc from its ore is certainly facilitated by the interposition of the copper.

MERCURY.

PART XLII.

SECT. I.

NATURAL HISTORY OF MERCURY.

MERCURY is found in five different states in nature; it is found native *(native mercury)* adhering in small globules to the surface of cinnabar ores, or scattered through the crevices, or over the surfaces of different kinds of stones. It is found united to silver, in the ore called *amalgam of silver*, or *native amalgam*. This ore exhibits thin plates, or grains; it sometimes crystallizes in cubes, parallelopipeds, or pyramids. Its colour is of a silver white, or gray; its lustre is considerably metallic. Combined with sulphur it constitutes *native cinnabar*, or sulphuret of mercury. This ore is the most common. It is frequently found in veins, and sometimes crystallized in tetrahedra, or three-sided pyramids. Its colour is red. Its streak metallic. Mercury, united either to muriatic or sulphuric acid, forms the ore called *horn-quicksilver*, or corneous mercury. These ores are, in general, semitransparent, of a gray or white colour, sometimes crystallized, but more frequently in grains. United to oxygen it constitutes the ore called *native oxyd of mercury*. Mercurial ores particularly abound in Spain, Hungary, Idria, China, and South America.

PROPERTIES OF MERCURY.

Mercury, or quicksilver, is the only one of the metals that remains fluid at the ordinary temperature of the

atmosphere; but when its temperature is reduced to—40° Fahr. it assumes a solid form. This is a degree of cold, however, that only occurs in high northern latitudes, and, in our climate, mercury cannot be exhibited in a solid state, but by means of artificial cold. When rendered solid, it possesses both ductility and malleability. It crystallizes in octahedra, and contracts strongly during congelation. It is divisible into very small globules. It presents a convex appearance in vessels to which it has little attraction, but is concave in those to which it does not adhere. It becomes electric and phosphorescent by rubbing upon glass, and by agitation in a vacuum. It is a very good conductor of caloric, of electricity, and of galvanism. The specific gravity of mercury is 13.563. Although fluid, its opacity is equal to that of any other metal; and its surface when clean, has considerable lustre. Its colour is white, similar to silver. Exposed to the temperature of 600° Fahr. it is volatilized.* When agitated in the air, especially in contact with viscous fluids, it becomes converted into a black oxyd. At a temperature nearly the same as that at which it boils, it absorbs about 14 or 16 per cent. of oxygen, and then becomes changed into a red crystallizable oxyd, which is spontaneously reducible by caloric and light at a higher temperature. The greater number of the acids act upon mercury, or are at least capable of combining with its oxyds. It combines with sulphur by trituration, but more intimately by heat. It is acted on by the alkaline sulphurets. It combines with many of the metals; these compounds are brittle, or soft, when the mercury is in large proportion. There is a slight union between mercury and phosphorus. It does not unite with carbon or the earths.

METHOD OF OBTAINING MERCURY.

Mercury may be obtained pure by decomposing cinnabar, by means of iron filings. For that purpose take two parts of red sulphuret of mercury (cinnabar) reduce it to powder, and mix it with one of iron filings; put the mixture into a stone retort, direct the neck of it into a bottle, or receiver, filled with water, and apply heat, until the retort is obscure red-hot. The mercury will then be obtained in a state of purity.

* About 660° Fahr. Davy.

RATIONALE....Sulphuret of mercury consists of sulphur and mercury; if this be heated in contact with iron, the sulphur quits the mercury and unites to the iron, and the mercury becomes disengaged; the residue in the retort is a sulphuret of iron.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF MERCURY.

EXPERIMENT I.

Mercury is volatilized by heat.

THIS method is employed with advantage for purifying mercury, by separating it from substances more fixed than itself.

For this purpose put mercury into a retort, and adapt to its beak a small bundle of tow, or lint, adjust a matrass containing water to the retort, and proceed to distillation. When the mercury is pure, it passes over entirely: if it contains foreign matters, they are left at the bottom of the retort. Sometimes it leaves a little gray powder, which is mercury oxydated by the air contained in the vessels.

EXPERIMENT II.

Mercury combines with sulphur.

Put into a stone mortar one part of mercury, and three of sulphur reduced to a fine powder; triturate them together, and moisten the mixture with a little water until the mercury perfectly disappears; the result will be a black hydro-sulphuret of mercury.

EXPERIMENT III.

Preparation of cinnabar, or red sulphuret of mercury.

This is a more intimate combination of sulphur with mercury than the former, and is prepared in the following

manner. Melt in a crucible one part of pounded sulphur, and add to it four of mercury; stir the mixture, in order to assist the union of the substances. When they begin to combine, the mixture takes fire spontaneously: quench the flame, by covering the crucible; and having suffered the matter to cool, pulverize it in a marble mortar.

Put the powder resulting from it, which is of a violet colour, into a Florence flask; place it on a sand-bath, and proceed to sublimation, by exposing the vessel to a gradually increasing heat till the bottom of the crucible becomes red, and maintain it in that state for some time, suffer the vessel to cool, and having broken it, separate the cinnabar which has sublimed.

Mr. Kirchoff has made us acquainted with another method of obtaining cinnabar, more simple and elegant than the former, which is as follows.

Experiment IV.

Let 300 grains of mercury, and 68 of sulphur, with a few drops of a solution of potash to moisten them, be triturated in a Wedgwood's, or glass mortar, until it be converted into a black powder. Add to this 160 grains of potash, dissolved in as much water. Heat the vessel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. As the liquor evaporates, add water from time to time, so that the black oxyd may be constantly covered, to the depth of an inch. The trituration must be continued until the mixture begins to change from its original black colour to a brown, which usually happens when a large part of the fluid is evaporated; it then passes very rapidly to a red. No more water is now to be added, but the trituration is to be continued. When the mass has acquired the consistence of a jelly, the colour increases in brightness, with an incredible degree of quickness. The instant it has acquired its utmost beauty the heat must be withdrawn, otherwise its brilliancy will be impaired, and the red will pass to a brown colour. This red powder is also sulphuret of mercury or cinnabar,

Remark....Until lately cinnabar was considered to be a compound of the red oxyd of mercury and sulphur; but Mr. Proust has shown that it is composed of about 15 parts

of sulphur, and 85 of mercury, and that it differs from the preceding preparation, in not containing hydrogen.

Count de Moussin Pouschin has discovered that its passing to a brown colour may be prevented by taking it from the fire as soon as it has acquired a tolerable red colour, and placing it for two or three days in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. During this exposure the red colour gradually improves, and at last becomes excellent. He discovered also that, when the sulphuret is exposed to a strong heat, it becomes instantly brown, and then passes to a dark violet; when taken from the fire it acquires a beautiful carmine red.

Experiment V.

*Preparation of phosphuret of mercury.**

Put into a Florence flask equal parts of red oxyd of mercury, and phosphorus; add one part of water and place the flask on a sand-bath, taking care to shake it frequently, and not to remove it from the bath too early; it will soon become blackish, and in that state the mercury remains united to the phosphorus. The water becomes sensibly acid from the formation of phosphoric acid.

Rationale....In this experiment the oxygen of the oxyd of mercury quits that metal to join a portion of the phosphorus, which it converts into phosphoric acid; the mercury, thus deprived of its oxygen, and greatly divided, unites with the remainder of the phosphorus, and forms a peculiar combination, in which phosphorus predominates. The product becomes soft in boiling water, and regains its consistence when the water ceases to be warm.

Experiment VI.

Mercury decomposes sulphuric acid.

Put into a glass retort two parts of mercury, and three of concentrated sulphuric acid; convey the neck of the retort under a receiver in the pneumatic apparatus, and expose the mixture to heat; a strong effervescence is gra-

* It can be combined directly with phosphorus: Davy used calomel for the purpose. It has not been combined with hydrogen, azot, or carbon. Davy.

dually excited, the surface of the mercury becomes white, and a powder of the same colour is separated, which renders the acid turbid by dispersing itself through it.

In this operation a great deal of sulphureous acid gas is disengaged.

If the heat be continued till no more gas issues from the retort, a white opaque mass will be obtained, which is exceedingly caustic, and attracts moisture of the atmosphere. This mass is an *oxy-sulphate of mercury.* When water is poured upon it part of the acid is separated, and the salt assumes the form of a yellow powder, formerly called *turpeth* or *turbith mineral.*

The white saline mass is of various natures and properties, according as a greater or less quantity of acid has been used, and according to the length of time the heat has been applied; as will be seen in the following experiment.

Experiment VII.

Preparation of sulphates of mercury.

Let two parts of mercury be boiled in a retort, with three of concentrated sulphuric acid; interrupt the operation as soon as the mercury has been converted into a white mass. After refrigeration decant the fluid from this mass, and wash it in a little cold distilled water. This saline compound is *a super-sulphate of mercury.*

If this super-sulphate of mercury be repeatedly washed in cold distilled water, until the water which is decanted ceases to redden litmus paper, there remains behind a white mass, which is a *sulphate of mercury.*

Experiment VIII.

Mercury is not acted on by muriatic acid alone, but may be combined with it by double affinity.

Let equal parts of dry sulphate of mercury, and dry muriate of soda, be accurately mingled by trituration in a stone mortar; put the mass into a glass retort, and heat it on a sand-bath. A white salt will sublime in the shoulder of the retort, which is commonly called *corrosive sublimate of mercury.*

RATIONALE.....In this process the sulphuric acid of the oxyd unites to the soda of the common salt, and the muriatic acid of the latter combines with the mercurial oxyd, and forms a new compound.

EXPERIMENT IX.

Preparation of mild muriate of mercury.

If four parts of corrosive muriate of mercury be well mingled by trituration with three of mercury, they assume the form of a gray powder. If this powder be sublimed in a sand-heat, either from an ordinary phial placed in a crucible-bath for small experiments, or from a bolthead in the large way, a white crystalline sublimate is obtained, which must be carefully separated from the unsublimed gray powder and running mercury. The product thus obtained is a combination of a very imperfect oxyd of mercury with muriatic acid, called *mild muriate of mercury (calomel, or mercurius dulcis.)*

RATIONALE.....Mild muriate of mercury, or calomel prepared by the above process, is produced in the following manner: The fluid mercury deprives the perfect oxyd, which is combined with muriatic acid in the corrosive sublimate, of part of its oxygen; in other words, it is oxydated at the expense of that oxyd. Both the perfect oxyd and the mercury are thus changed into an imperfect mercurial oxyd, which the muriatic acid is capable of saturating, notwithstanding the quantity of the oxyd has been augmented. The redundant imperfect oxyd, and also the redundant fluid mercury, are separated from the mild muriate by its sublimation.

EXPERIMENT X.

Mercury decomposes nitric acid with great rapidity.

When diluted nitric acid is poured upon mercury, a violent action takes place, and nitrous gas is disengaged, the metal is gradually oxydated, and dissolved in that portion of the acid which remains undecomposed. If the solution be evaporated it yields crystals, which are *nitrate of mercury.*

REMARK.....When a concentrated acid is made to act upon mercury, or if the action be assisted by heat, the metal combines with a greater portion of oxygen, and a white precipitate falls down, which is an *oxy-nitrate of mercury.*

EXPERIMENT XI.

Preparation of red oxyd of mercury.

For this purpose let the nitrate of mercury obtained in the last experiment be pulverized in a glass mortar, and put into one or more matrasses placed on a sand-bath; the vessels are then to be gradually heated until the contents become of a yellow colour at the surface; suffer them to cool, and the matter they contain will be found in strata of different colours. The lower part is of a bright red colour, and the upper of an orange yellow. The mass, when pulverized, is *red oxyd of mercury.*

EXPERIMENT XII.

Mercury readily unites to gold, silver, copper, &c.

This may be evinced by rubbing a little mercury on a gold, silver, or copper coin. Or, the combination may be facilitated by igniting the coin, and in that state conveying it into hot mercury. The mercury may be again expelled by heat. These alloys are called *amalgams.*

EXPERIMENT XIII.

Mercury is not oxydated at ordinary temperatures; but when its temperature is raised nearly to that at which it boils, it combines with oxygen.

Put into a flat-bottomed matrass with a long narrow neck, as much mercury as is sufficient to cover the bottom of it to the height of a line or two; fuse the neck of the vessel by means of a blow-pipe, draw it out to a fine point, and form it into a capillary tube: instead of breaking the point to afford access to the external air, it is better to

pierce the bulb of the matrass at the centre, and adjust to the hole a bent tube immersed in atmospheric air, in such a manner that the air may be renewed much easier, and enter in greater quantity, which facilitates the operation. Place the apparatus in a sand-bath, expose it to heat till the mercury boils, and maintain the fire at the same degree for several days. The oxyd formed at the surface of the mercury is separated by means of a piece of linen cloth, which is pressed. The mercury passes through it while the oxyd remains behind; and this operation must be continued till the mercury is completely oxydated.

This substance has been called *mercury precipitated per se*, or red precipitate of mercury without acid: it is a real oxyd of mercury, or a combination of this metal with oxygen, which it gradually takes from the atmosphere. It contains about 7 per cent. of oxygen.

Experiment XIV.

Preparation of fulminating mercury.

It has been lately discovered by Mr. Howard, that mercury, and most, if not all of its oxyds, may, by treatment with nitric acid and alcohol, be converted into a whitish crystallized powder, possessing all the inflammable properties of gun-powder, as well as many peculiar to itself. It is obtained in the following manner.

One hundred grains (or a greater proportional quantity, not exceeding 500) are to be dissolved, with heat, in a measured ounce and a half of nitric acid. This solution being poured *cold* upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action and re-union. The precipitate is to be immediately collected on a filter, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water-bath. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid; and while any of the acid adheres to it, it is very subject to the action of light. From 100

grains of mercury about 120 or 130 of the powder are obtained.*

This powder, when, struck on an anvil with a hammer, explodes with a stunning disagreeable report; and with such force as to indent both the hammer and the anvil. Three or five grains are as much as ought to be used for such experiments.

The shock of an electric battery sent through it produces a very similar effect.

A quantity of it sufficient to discharge a bullet from a gun, with a greater force than an ordinary charge of gunpowder, always bursts the piece.

From a series of well-conducted experiments, Mr. Howard concludes that this preparation consists of oxyd of mercury, oxalic acid, and nitrous etherized gas. Its detonation is owing to the sudden combination of the oxygen with the carbon and hydrogen of these substances, forming aqueous vapour and carbonic acid, and disengaging nitrogen gas; while at the same time so much caloric is suddenly liberated that the elasticity of the gases is not only increased, but the mercury is instantaneously converted into vapour.

Experiment XV.

Congelation of Mercury.

The freezing of mercury was until lately a difficult experiment. We are indebted to Mr. Pepys for an easy method of effecting this. This gentlemen, with the assistance of some friends, froze, in the winter of 1799, 56lb. of mercury into a solid and malleable mass. The process was as follows.

The mercury was put into a strong bladder, and well secured at the mouth.

The temperature of the laboratory at the time being + 33°. A mixture consisting of muriate of lime, 2lb. at + 33°, and the same weight of snow at + 32°, gave a

* Philosoph. Trans. 1800, p. 214.

degree of cold—42°. The mercury was put as gently as possible into this mixture, (to prevent a rupture of the bladder) by means of a cloth held at the four corners. When the cold mixture had robbed the mercury of so much of its heat, as to have its own temperature thereby raised from—42° to +5°, another mixture, in every respect the same as the last, was made, which gave on trial with a spirit-thermometer—43°. The mercury was now received into the cloth, and put gently into this new mixture, where it was left to be cooled still lower than before.

In the mean time five pounds of muriate of lime, in a large pail made of tinned iron, and japanned inside and outside, was placed in a cooling mixture in an earthenware pan. This mixture in the pan, which consisted of 4lb. of muriate of lime, and a like quantity of snow of the same temperature as the former, in one hour reduced the 5lb. of muriate in the pail, to—15°. The mixture was then emptied out of the earthen pan, and four large corks, at proper distances, placed on its bottom to serve as rests for the japanned pail, which was now put into the pan. The corks answered the purpose of insulating the inner vessel, while the external one kept off the surrounding atmosphere, and preserved the air between the two at a low temperature.

To the 5lb. of muriate of lime which had been cooled, as already noticed, to—15°, and which still remained in the metallic vessel, was now added snow, uncompressed and free from moisture, at the temperature of 32°. In less than three minutes it gave a temperature of—62°, a degree of cold which was never produced before in this country, being 94° below the freezing point of water.

The mercury which, by the immersion in the second cooling mixture to which it was exposed, was by this time reduced to—30°, was now, by the means employed before, cautiously put into the last made mixture of the temperature of—62°. A hoop, with net-work fastened to its upper edge, and of such a breadth in the rim, that the net-work, when loaded with the bladder of mercury, could not reach its lower edge, was at the bottom of the

mixture, to prevent the bladder from coming in contact with the vessel; by which means the mercury was suspended in the middle of the mixture. As soon as the bladder was safely deposited on the net-work, the vessels were carefully covered over with a cloth, to impede the passage of heat from the surrounding atmosphere into the freezing materials. The condensation of moisture from the atmosphere, by the agency of so low a temperature, was greater than could have been expected. It floated like steam over the vessels, and but for the interposed covering would have given the mixture more temperature than was desirable.

After one hour and forty minutes they found, by means of a searcher introduced for the purpose, that the mercury was solid and fixed. The temperature of the mixture at this time was—46°, that is, 16° higher than when the mercury was put into it. As they had neglected to sling the hoop and net-work in such a manner as might have enabled them to lift it out of the mixture at once with the bladder and its contents, it was therefore necessary to turn out the whole contents of the pail into a large evaporating capsule made of iron. This was not affected without the mercury striking against its bottom and being fractured, though it received a considerable increase of temperature from the capsule. The fracture was similar to that of zinc, but with parts more cubical.

The large pieces were kept for some minutes before fusion took place, while others were twisted and bent into various forms, to the no small gratification and surprise of those who had never witnessed, or expected to see such an effect produced on so fusible a metal.

Remark....In experiments of this kind all the exterior vessels should be of earthen-ware, glass, or wood, which being bad conductors of heat, prevent the ingredients from receiving it from the atmosphere, and surrounding objects, with the same facility that they would through metals; and for a similar reason the interior vessels should be of metal, that they may allow the heat to pass more readily from the substance to be cooled into the frigorific mixture employed for that purpose. If this be attended to, a small quantity of mercury (2 to 4 oz.) may easily be

frozen by means of the above mixture, in a pewter pint-pot placed in a bason.

ANALYSIS OF ORES OF MERCURY.

Ores of mercury are best analysed by distilling them in a strong heat, and adapting a receiver half filled with water. The native cinnabar is decomposed by distilling it with one part of lime or iron filings, to three of the ore.

TELLURIUM.

PART XLIII.

NATURAL HISTORY OF TELLURIUM.

THIS is a new metal discovered by Klaproth, in the year 1797. It is found in three different ores; namely, 1. In the *white gold ore of Fatzebay*, formerly named *aurum paradoxum*, found in the mine called Maria-hilf, in the mountains of Fatzebay, near Zalethna, in Transylvania. In this ore Tellurium exists alloyed with gold and iron. Its colour is between tin-white and lead-gray. It is in general found massive. The texture of this ore is granular, and its lustre considerably metallic. 2. In the *graphic gold ore*, *(aurum graphicum)* of Offenbanya, it is alloyed with gold and silver. This ore is composed of flat prismatic crystals, the arrangement of which has some resemblance to Turkish letters; hence the name of the ore. It has a metallic lustre, and a tin-white colour, with a tinge of brass-yellow. 3. It exists also in the ore known under the name of the *yellow foliated gold ore of Nagyag;* alloyed with gold, lead, silver, copper, and sulphur. This ore is found in plates of different degrees of thickness. Its colour is of a deep lead-gray, passing to iron-black. It has a considerable metallic lustre, and stains the fingers.

PROPERTIES OF TELLURIUM.

The colour of Tellurium is white, like that of tin, but inclining to a leaden-gray. It has a considerable metallic lustre. Its texture is lamellated, like antimony. It is exceedingly brittle and friable. If it be fused, and suffered to cool gradually, undisturbed, it readily assumes a crystallized surface. Its specific gravity is 6.115. It is one of the most fusible metals, melting as easily as tin. Heated with the blow-pipe, it burns with a brilliant blue flame, greenish at the edges; and it is so volatile as to

rise totally into gray whitish fumes, emitting a disagreeable odour, approaching to that of radishes. It forms, with sulphur, a gray radiated sulphuret, and alloys very well with mercury. It is soluble in the nitric and nitro-muriatic acids; the latter solution is decomposable by water. It is likewise soluble in boiling concentrated sulphuric acid. The solution acquires a fine red colour, which is lost either by heating it, or by the addition of water.

These are the principal physical properties of this metal.

METHOD OF OBTAINING TELLURIUM.

Tellurium is obtained, according to Klaproth, by forming oxyd of tellurium into a paste, with a few drops of linseed oil, and then putting it into a small glass retort, or crucible. As the oil becomes decomposed, brilliant and metallic drops are observed on the upper part of the vessel, which increase in number until the oxyd is revived.

The process for obtaining oxyd of tellurium may be seen in the following

ANALYSIS OF ORES OF TELLURIUM.

Let the white gold ore be gently heated with six parts of muriatic acid; three parts of the nitric being then added, the mixture is boiled, upon which there arises a considerable effervescence, and a complete solution is obtained. The filtered solution must be diluted with as much water as it can bear without becoming turbid, which is a very small quantity; and a solution of potash is then to be added to the liquor, until the white precipitate, which is at first formed, disappears, and nothing remains but a brown flaky sediment, which is the oxyd of gold mixed with the oxyd of iron contained in the ore. This may be dissolved in nitro-muriatic acid; and the gold be precipitated by a solution of nitrate of mercury, and then the iron by potash. Muriatic acid is then added to the before obtained alkaline solution, in sufficient quantity to saturate the potash. An excess of the acid must be avoided. A white precipitate is thus produced in great abundance. This, when washed, is the oxyd of tellurium.

ANTIMONY.

PART XLIV.

SECT. I.

NATURAL HISTORY OF ANTIMONY.

ANTIMONY is found *native*, but very rarely: it has, in that state, a metallic lustre, and is found in masses of different shapes: its colour is white, between that of tin and silver. It generally contains a small portion of arsenic. It is likewise met with in the state of an oxyd, *antimonial ochre*. The most abundant ore of it is that in which it is combined with sulphur, *the gray ore of antimony*, or *sulphuret of antimony*. The colour of this ore is bluish, or steel-gray, of a metallic lustre, and often extremely beautifully variegated. Its texture is either compact, foliated, or striated. The striated is found both crystallized, massive, and disseminated: there are many varieties of this ore.

PROPERTIES OF ANTIMONY.

Antimony is of a grayish white, having a slight bluish shade, and very brilliant. Its texture is lamellated, and exhibits plates crossing each other in every direction. Its surface is covered with herbarizations and foliage. Its specific gravity is 6.702. It is sufficiently hard to scratch all the soft metals. It is very brittle, easily broken, and pulverizable. It fuses at 810° Fahr. It can be volatilized, and burns by a strong heat. When perfectly fused, and suffered to cool gradually, it crystallizes

in octahedra. It unites with sulphur and phosphorus. It decomposes water strongly. It is soluble in alkaline sulphurets. Sulphuric acid, boiled upon antimony, is feebly decomposed. Nitric acid dissolves it in the cold. Muriatic acid scarcely acts upon it. The oxygenated muriatic acid gas inflames it, and the liquid acid dissolves it with facility. Arsenic acid dissolves it by heat with difficulty. It unites, by fusion, with gold, and renders it pale and brittle. Platina, silver, lead, bismuth, nickel, copper, arsenic, iron, cobalt, tin, and zinc, unite with antimony by fusion, and form with it compounds, more or less brittle. Mercury does not alloy with it easily. We are little acquainted with the action of alkalies upon it. Nitrate of potash is decomposed by it. It fulminates by percussion with oxygenated muriate of potash.

METHODS OF OBTAINING ANTIMONY.

1. To obtain antimony, heat 32 parts of filings of iron to redness, and project on them, by degrees, 100 parts of antimony; when the whole is in fusion, throw on it, by degrees, 20 parts of nitrate of potash, and after a few minutes quiet fusion pour it into an iron melting cone, previously heated and greased.

2. It may also be obtained by melting eight parts of the ore mixed with six of nitrate of potash, and three of acidulous tartrite of potash,* gradually projected into a red-hot crucible, and fused.

To obtain perfectly pure antimony, Margraaf melted some pounds of the sulphurated ore in a luted crucible, and thus scorified any metals it might contain. Of the antimony thus purified, which lay at the bottom, he took sixteen ounces which he oxydated cautiously, first with a slow, and afterwards with a strong heat, until it ceased to smell of sulphur, and acquired a grayish white colour. Of this gray powder he took four ounces, mixed them with six drachms of acidulous tartrite of potash, and three of charcoal, and kept them in fusion in a well covered and luted crucible, for one hour, and thus obtained a metallic button that weighed one ounce, seven drachms, and twenty grains.

* Acidulous tartrite of Potash, is purchased when purified under the name of cream of tartar: cream of tartar is made by dissolving, filtering, and crystallizing the tartar of wine casks, known in commerce by the name of Argol. T. C.

The metal, thus obtained, he mixed with half its weight of desiccated carbonate of soda, and covered the mixture with the same quantity of the carbonate, He then melted it in a wet covered and luted crucible, in a very strong heat, for half an hour, and thus obtained a button which weighed one ounce, six drachms, and seven grains, much whiter and more beautiful than the former. This he again treated with one and a half ounce of carbonate of soda, and obtained a button, weighing one ounce, five drachms, and six grains. This button was still purer than the foregoing. Repeating these fusions with equal weights of carbonate of soda three times more, and an hour and a half each time, he at last obtained a button so pure as to amalgamate with mercury with ease, very hard, and in some degree malleable; the scoriæ formed in the last fusion were transparent, which indicated that they contained no sulphur, and hence it is the obstinate adherence of the sulphur that renders the purification of this metal so difficult.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF ANTIMONY.

Experiment I.

Antimony combines with different portions of oxygen.

WHEN antimony is beaten to powder, and exposed for some time to a dull red heat, in an open vessel, it absorbs oxygen, and is converted into a gray powder. This is called *gray oxyd of antimony.*

When the metal is exposed to a higher temperature the product is *white oxyd of antimony.* For instance,

Place a triangular crucible in a furnace, not vertically, but in the manner of a muffle, with its bottom somewhat inclined. Its mouth must project a little without the door, through which it is introduced into the furnace, and it may be luted in that position. Put some metallic antimony into it, and place over its mouth another crucible, to receive the oxyd. Bring the metal to a white heat,

and remove the upper crucible every half hour, putting another in its place; these will be filled with a white silvery looking substance, which must be detached with a feather. This is *white oxyd of antimony.*

If this or the former oxyd be exposed to a more violent heat, it fuses into a transparent vitreous mass, which varies in colour from a faint yellow to a dark red hyacinth, or orange colour. This is called *vitreous oxyd of antimony, or glass of antimony.*

To ascertain if the fusion be perfect, immerse an iron rod into it, and, when taken out, examine the substance which adheres to it: if it be transparent, and can be easily drawn into a fine thread like common glass, the fusion is complete; then remove the crucible from the fire, and pour out its contents on a heated plate of copper.

All these products are imperfect oxyds of antimony.

When nitrate of potash is decomposed by antimony the result is a combination, known under the name of diaphoric antimony, which is a more perfect oxyd than the former.

Experiment II.

*Preparation of perfect oxyd of antimony.**

Let equal parts of nitrate of potash and sulphuret of antimony be intimately blended together; project the mixture, by small quantities, into a crucible brought to a red-heat; on every addition of the mixture a detonation will take place. When the whole has been thrown into the crucible, expose it to a heat sufficient to bring the matter into a state of fusion: then take the crucible from the fire, and having suffered it to cool, separate the scoriæ from the oxyd of antimony, which will be found in the form of a brown opaque mass.

Remark....Native or crude antimony, as it is called, and which is obtained by the smelting of different antimonial ores, has the same nature and properties as the factitious sulphuret of antimony.

When this substance is prepared in pharmacy, the native

* The pulvis algaroth, or powder of algaroth, a precipitate by water from a solution of muriate of antimony, is the fusible oxyd of antimony; which by being heated in contact with atmospheric air, imbibes still more oxygen. Davy.

sulphuret is generally used. In this case a larger quantity of nitrate of potash is required to be added, as for example, three parts to one of the mineral, in order that all the sulphur, as well as the metal to which it is united, may be completely oxydated. The reason why the ore is preferred in this process is, that the sulphur renders the detonation more rapid, and facilitates the combination of the antimony.

If the mixture is not brought to fusion, only vitreous scoriæ will be obtained: the nitrate of potash, in this case, is not sufficient to change all the sulphur of the native sulphuret into sulphuric acid to oxydate the metal completely. This matter, when reduced to powder, and washed in water forms *crocus metallorum*, which is only a semi-vitreous oxyd of antimony, pulverized and separated from the saline matters which arise from the detonation of the nitrate of potash.

Experiment III.

Combination of antimony with phosphorus.

(Phosphuret of antimony.)

To obtain this substance, mix together equal parts of glacial acid of phosphorus and antimony, and one-eighth of powdered charcoal; fuse the whole in a crucible, the result will be a white brittle metallic substance, having a lamellated fracture when broken, and at the fracture appear a number of small cubic facets. When melted it emits a green flame, and sublimes in the form of a white powder.

Phosphuret of antimony may also be obtained by projecting phosphorus on red-hot antimony. Care must be taken to remove the crucible from the fire as soon as the last portions of the phosphorus have been added: without this precaution nearly all the phosphorus would be volatilized.

Experiment VI.

Combination of antimony with sulphur.

(Sulphuret of antimony.)

To procure sulphuret of antimony, pulverize equal parts of sulphur and antimony, put the mixture into a

crucible, cover it, and expose it to a heat sufficient to make the crucible slightly red; when the matters are fused, take the crucible from the fire, suffer it to cool, and the contents will be found to be a brilliant radiated mass of a lead or slate-gray colour.

Experiment V.

Preparations of hydrogenated hydro-sulphuret of Antimony.

Into a boiling ley of pure potash dissolved in about three or four times its weight of water, throw sulphuret of antimony equal to a sixteenth of the alkali employed. Stir the mixture well, and after it has boiled a little, filter it. On cooling, this liquor will deposit an abundant precipitate, which must be washed, first with cold, and afterwards with boiling water, until it becomes insipid: when dry, pulverize it and sift it through a silk sieve. Or,

Boil ten or twelve parts of pure liquid alkali with two of sulphuret of antimony; keep the mixture in a state of ebullition for half an hour, then filter it, and on cooling a precipitate will be obtained. Digest the alkali again over more sulphuret, until it exercises no further action upon it. Wash and dry the product as before.

To these processes, we shall add that of Deyeux; and those who prepare medicines of this kind on a large scale will no doubt see the details he has communicated, with pleasure.

Take carbonate of potash one part; sulphuret of antimony, pounded small, four parts; river water, filtered, eight parts.

Boil the whole in a very clean iron vessel for a quarter of an hour; then take out a small quantity of the liquor with an iron spoon, and if, as the liquor cools, it becomes turbid, and forms a reddish deposit, it contains kermes in solution. Should the contrary be the case, continue the ebullition till the above phenomena are manifested; then pour the boiling liquor on a filter of paper, placed on a piece of pretty thick cloth: the liquor will pass exceedingly clear; but as it reaches the bottom of the jar placed to receive it, it becomes turbid, and deposits an abundant precipitate.

During the filtration of the liquor, carbonate of potash and water, each equal in quantity to that first employed, are to be added to the sulphuret which remains in the iron vessel and boiled as before. This operation is to be repeated four times, and the liquor obtained from each is to be filtered separately.

During the fourth operation, the filtered liquors of the two first will have deposited the kermes they contained. They must be carefully decanted, and the liquors boiled again with the sulphuret of antimony, which has remained in the iron vessel.

The same method must be observed with the liquors of the third and fourth operation, and so repeated until the whole of the kermes has been obtained; but as the water and alkali decrease as the operations are repeated, care must be taken to add, from time to time, a solution of carbonate of potash, observing that the quantity be not too great, otherwise the kermes will remain in solution in the liquor and not be deposited on cooling.

Care must also be taken to renew the paper filters frequently, as their pores speedily become closed. Each time they are changed, the matter deposited upon them must be returned into the boiler.

The kermes deposited in the jars during each operation must be put into a separate vessel, and suffered to remain there till the requisite quantity is obtained; it must then be freed from the alkali with which it is still moistened, and dried.

For this purpose, after having carefully decanted the supernatant fluid, wash the precipitate in a large quantity of river-water, which should be filtered and as cold as possible; suffer it to settle and decant it; and repeat the washing until the decanted liquor has no alkaline taste.

The precipitate collected at the bottom of the last water must be thrown on several paper filters, placed either in funnels or over pieces of cloth, in such a manner that the matter on each filter may be about two inches in thickness. As the moisture drains off, the kermes shrink, crack and acquire a consistence. A small quantity of it must be taken from time to time to examine what state it is in, and when, by touching it with a spatula, it begins to divide itself without daubing, put it between two leaves of paper, and having wrapped it in a linen cloth, put it

under a press, and then suffer it to dry in a very moderate temperature.

REMARK.....This process is indeed longer and more tedious than the former, but it yields a product of a beautiful colour, and whose medicinal effects never vary.

A product of the same nature is that formerly called sulphur of antimony, but now hydrogenated sulphurated oxyd of antimony.

EXPERIMENT VI.

Preparation of hydrogenated sulphurated oxyd of antimony.

This product may be obtained by letting fall either nitric, sulphuric, or muriatic acid into the fluid in which the hydrogenated hydro-sulphuret of antimony has been formed, and from which it has been entirely separated by cooling. This fluid becomes again turbid by the addition of the acid, and there is formed in it a second precipitate, which is a reddish-yellow, or orange-coloured hydrogenated sulphurated oxyd of antimony. If the liquor be filtered and more acid added, another precipitate will ensue, but less coloured.

This oxyd is, however, in general more expeditiously obtained by boiling two parts of sulphuret of antimony and three of sulphur, both reduced to fine powder, with a sufficient quantity of water in an iron pot, filtering the liquor, and precipitating it with diluted sulphuric acid. The product obtained contains about 75 parts of sulphur in 100.

RATIONALE....All these processes consist in uniting, in a more or less direct manner, the oxyd of antimony with sulphurated hydrogen. It is, as Fourcroy has observed, the uniform effect which it has produced by all the alkalies, whether they are employed hot or cold, with sulphuret of antimony; they first oxydate the metal, and form with the sulphur a sulphuret charged with hydrogen; this unites with the oxyd of the metal which remains in solution. The alkaline sulphuret precipitated afterwards by an acid, in the form of an orange-coloured powder, is in reality nothing but an oxyd of antimony, surcharged with sulphurated hydrogen and sulphur.

The principal difference between this preparation and the former consists in this, that the first contains sulphurated oxyd of antimony in addition to the hydro-sulphuret of antimony of the latter. In a word, there is no reason to doubt that it is to the sulphurated hydrogen in the mineral kermes that this medicine is indebted for the virtues by which it is characterised.

Experiment VII.

Antimony decomposes oxygenated muriate of mercury.

Mix intimately one part of antimony with two of oxygenated muriate of mercury, and introduce the mixture into a glass retort with a wide aperture, leaving about one-third of it empty. Place the retort on a sand-bath, in a reverberating furnace; adjust to the retort a receiver whose capacity is two-thirds less than that of the retort, and proceed to distillation with a gentle heat. During the first half hour there passes over a clear white liquor, followed by another which becomes fixed into a white mass in the receiver: this is what is called *oxygenated muriate of antimony*, formerly termed, from its consistence, *butter of antimony*. As this substance often choaks up the neck of the retort, a burning coal must be applied, to melt it, and make it pass into the receiver. The distillation is to be continued till nothing more passes over, after which the vessels are suffered to cool; and the receiver being unluted, is exposed to a gentle heat, above a chafing-dish, to liquefy the oxygenated muriate of antimony.*

The properties of this compound are the following: It is exceedingly caustic, and instantly destroys the organs of the body. It burns vegetable matters. It fuses by a low degree of heat, and becomes fixed on cooling. It readily loses its whiteness. It is alterable by light. It strongly attracts the moisture of the atmosphere, and resolves itself into a thick, and, as it were, oleaginous fluid. It crystallizes in very large parallelopipeda. It is very difficult to keep it in a solid state. It has the property also of being partly soluble in water, and of being decomposed, in a great measure, by that fluid.

When it is thrown into distilled water, a white oxyd of antimony is very abundantly precipitated. This pow-

* Metallic antimony in powder, takes fire in chlorine, or oxymuriatic gas. T. C.

der, when washed several times in a large quantity of boiling water, and then dried, was formerly called *Algaroth's powder.*

RATIONALE.....In this operation the antimony robs the oxygenated muriate of mercury of part of its oxygen, and becomes oxydated; it then unites to most of the acid, with which it forms oxygenated muriate of antimony. If the distillation be continued after the oxygenated muriate of antimony has passed, fluid mercury will be obtained. Oxygen is therefore more strongly attracted by antimony than by mercury.

If sulphuret of antimony be exposed to distillation with oxygenated muriate of mercury, oxygenated muriate of antimony and red sulphuret of mercury *(cinnabar)* will be obtained. Upon this is founded the following process:

EXPERIMENT VIII.

Preparation of cinnabar of antimony.

Pulverize one part of sulphuret of antimony and three of oxygenated muriate of mercury, according to Baumé; but according to Fourcroy, one part of the former to two of the latter: mix these substances, and proceed in other respects as in the preceding operation. When the distillation is finished, adapt another receiver to the retort, and sublime the residuum with a strong heat. A substance will be obtained in the form of red needles, called cinnabar of antimony.

This is the effect of a double affinity. The sulphuret of antimony exchanges its sulphur for the acid given up by the oxygenated muriate of mercury.

The combination of antimony with other metals is not attended with any difficulty.

ANALYSIS OF ORES OF ANTIMONY.

These ores may be analysed by digesting by heat one part of the ore, reduced to a fine powder, in four parts of nitro-muriatic acid, composed of three or four of muriatic acid, and one of nitric acid. The sulphur contained in the ore will remain behind untouched. On

filtering the solution, the antimony must be disengaged by the mere admixture of water, and may be collected on a filter. To reduce it to the metallic state, let it be mixed with double its weight of charcoal and fuse it in a crucible. The metal will then be found at the bottom.

As lead and iron are sometimes present in these ores, they may be detected by letting fall into the last solution from which the antimony has been separated a few drops of sulphuric acid: if lead be present, a white precipitate will ensue; if iron be present, a yellowish-brown precipitate will take place on adding liquid ammonia to the solution.

BISMUTH.

PART XLV.

SECT. I.

NATURAL HISTORY OF BISMUTH.

BISMUTH is found in the earth in very few different states, more generally native, or in the metallic state. *Native bismuth* is met with in solid masses, and also in small particles dispersed in and frequently deposited on different stones; at Schneeberg, in Saxony, Sweden &c. Sometimes it is crystallized in four-sided tables, or indistinct cubes. It exists combined with oxygen in the *oxyd of bismuth, (bismuth ochre)* found in small particles, dispersed, of a bluish or yellowish-gray colour, needle-shaped and capillary; sometimes laminated, forming small cells. It is also, though more seldom, united to sulphur and iron, in the form of a sulphuret, in the *martial sulphurated bismuth ore.* This ore has a yellowish-gray appearance, resembling somewhat the martial pyrites. And it is sometimes combined with arsenic.

PROPERTIES OF BISMUTH.

Bismuth is of a silver white colour inclining to red. It soon tarnishes and becomes iridescent. It is brittle, and can easily be reduced to small particles. It is soft enough to be cut with a knife. It has a lamellated texture. Its specific gravity is 9.800. It requires less heat for fusion than any other metal, tin excepted, melting by a heat =460° Fahr.* It can be volatilized by heat, and escapes in the

* 476° Fahr. DAVY. A wire, .1 of an inch diameter supports 29 lb.

state of grayish-white vapour. It readily unites with mercury and with sulphur. When fused, it exhibits, on cooling, cubical figures on the surface. It is soluble in sulphuric, nitric, and muriatic acids. The solution in nitric acid is decomposable by mere dilution with pure water. It inflames in oxygenated muriatic acid gas. It is capable of combining with the greatest number of the metals; and when in certain proportions, promotes their fusibility remarkably. It speedily becomes black by sulphurated hydrogen gas.

METHOD OF OBTAINING BISMUTH.

To obtain bismuth from its ore, nothing more is necessary than to fuse the ore with an eighth part of white flux in a well-closed vessel. The metal obtained by this process, however, is far from being in a pure state. It forms the bismuth of commerce.

In order to purify it, let it be powdered, and dissolve it in pure nitric acid and precipitate it, by adding water to the solution. Collect the precipitate on a filter, form it into a paste with oil, and rapidly fuse it with black flux* in a closed crucible.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF BISMUTH.

Experiment I.

Nitric acid dissolves bismuth with great rapidity.

PUT some nitric acid into a Florence flask or common phial, and gradually add to it bismuth broken into small pieces till no more dissolves, then filter the solution. This solution, when evaporated and suffered to crystallize slowly, furnishes a white and exceedingly brilliant salt, which is *nitrate of bismuth.*

It is remarkable, that if this metallic salt be dissolved in pure water, it renders it white and milky, which is a criterion to distinguish this from other metals. The pre-

* Black flux, is potass containing carbon. Deflagrates together in a red heat 2 parts of crude tartar and one of nitre. See page 280.

cipitate which is thus formed is called *white oxyd of bismuth*, and is sold by perfumers under the name of *pearl white*.

Experiment II.

Preparation of white oxyd of bismuth.

Dissolve bismuth in pure nitric acid, diluted with an equal quantity of water. Let the solution stand undisturbed till it becomes perfectly transparent, then add a large quantity of distilled water; a precipitate will instantly be formed. When this has subsided, decant the super-natant fluid, and wash the white powder repeatedly in distilled water till it passes tasteless; then suffer it to dry spontaneously in the dark, and keep it in a glass bottle. 100 parts bismuth produce 123 parts of oxyd.

Remark....This oxyd is used as a cosmetic for whitening the skin but it is attended with this inconvenience, that it becomes *black* by coming into contact with fetid substances, &c. The eating of boiled eggs is capable of producing this effect. It is thought, and perhaps with reason, that this paint gradually impairs the skin. The liberal use of *any* paint for the skin seems likely to do this; but have we not reason to suspect, from the deleterious effects of this metal on the animal economy, that the liberal use of the oxyd of this metal may be attended with effects similar to those which the oxyds of lead are known to produce?

Experiment III.

Combination of bismuth with phosphorus.

Fuse bismuth in a crucible, and let fall upon it gradually small pieces of phosphorus. On removing the crucible from the fire, the phosphuret of bismuth will be found adhering strongly to the crucible.

Sulphuret of bismuth may easily be obtained by melting sulphur and bismuth together.

The union of bismuth with metals is not attended with any difficulty.

Experiment IV.

Oxyd of bismuth decomposes muriate of ammonia by heat.

Mix together one part of oxyd of bismuth and two of muriate of ammonia, put the mixture into a glass retort, furnished with a receiver containing a little water, and proceed to distillation: ammonia will pass over and be absorbed by the water in the receiver, and a little oxyd of bismuth, mixed with undecomposed muriate of ammonia, will rise and attach itself to the neck of the retort. The remainder, in the retort, is a combination of the metallic oxyd with muriatic acid, called *muriate of bismuth.**

ANALYSIS OF ORES OF BISMUTH.

Ore of bismuth and bismuth ochre are very easily examined. The ore called native bismuth may be analysed by treating it repeatedly with nitric acid assisted by heat. On adding water to the clear solution, the bismuth becomes precipitated in the form of a white powder. If the whole should not be precipitated at first, the solution should be concentrated by evaporation; then a second affusion of water will precipitate the remainder. This precipitate formed into a paste with a few drops of oil, and rapidly fused with black flux, gives a button of bismuth.

The rest of the ores of bismuth may be analysed in a similar manner. The sulphur which they contain will not be acted upon by the nitric acid; it will therefore be left behind, and may be separated by filtration.

* Bismuth in fine powder takes fire in chlorine gas. This is butter of bismuth. The mixture that melts in boiling water is, bismuth 8 parts, lead 5 parts, tin 3 parts. It has lately been used by Mr. Wolfe to retain heat in the cylinder of his steam engine. Davy.

MANGANESE.

PART XLVI.

SECT. I.

NATURAL HISTORY OF MANGANESE.

THIS metallic substance seems, after iron, to be the most frequently diffused metal through the earth; its ores are very common. As a peculiar metal, it was first noticed by Gahn and Scheele, in the years 1774 and 1777. It is always found in the state of an oxyd, varying in the degree of oxydation. La Perouse affirmed that he had found manganese in a metallic state; but there was probably some mistake in his observation. They are distinguished into *gray oxyd of manganese*, *black oxyd of manganese*, *reddish white oxyd of manganese*, and *carbonate oxyd of manganese*. All these combinations have an earthy texture; they are very ponderous; they occur both amorphous and crystallized; and generally contain a large quantity of iron. Their colour is black, blackish brown, or gray, seldom white. They soil the fingers like soot. They are sometimes crystallized in prisms, tetrahedral, rhomboidal, or striated.

PROPERTIES OF MANGANESE.

Manganese is of a whitish-gray colour. Its fracture is granulated, irregular, and uneven. It is of a metallic brilliancy, which it, however, soon loses in the air. Its specific gravity is about 6.850. It is very hard, and extremely brittle. It is one of the most refractory metals, and most difficult to fuse, requiring, at least 160° of Wedgwood's pyrometer. Its oxydability is said to be so rapid, that exposure to the air is sufficient to render it red, brown,

black, and friable, in a very short time; it can, therefore, only be kept under water, oil, or ardent spirit. It is the most combustible of all the metals. It decomposes water by heat very rapidly, as well as the greater part of the metallic oxyds. It decomposes sulphuric acid. It is soluble in nitric acid. It is fusible with earths, and colours them brown, violet, or red, according to its state of oxydation. It discolours glasses tinged by iron. It does not appear to unite with sulphur. It combines with phosphorus. It unites with gold, silver, and copper, and renders them brittle. It unites to arsenic in close vessels, but does not enter into union with mercury. It forms three different coloured oxyds by combining with different portions of oxygen.

METHOD OF OBTAINING MANGANESE.*

This metal is obtained by mixing the black oxyd, finely powdered, with pitch; making it into a ball, and putting this into a crucible, with powdered charcoal, $\frac{1}{10}$ of an inch thick at the sides, and $\frac{1}{4}$ of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal; a cover is to be luted on; and the crucible exposed, for an hour, to the strongest heat that can be raised. Or, digest the black oxyd of manganese repeatedly, with the addition of $\frac{1}{16}$ of sugar, in nitric acid; dilute the mixture with three times its bulk of water, filter it, and decompose it by the addition of potash; collect the precipitate, form it into a paste with oil, and put it into a crucible, well lined with charcoal. Expose the crucible for at least two hours to the strongest heat of a forge.

Manganese may also be obtained in the following manner:

Prepare a saturated solution of sulphate of manganese, bring it to a boiling heat, and add to it gradually, a solution of tartrite of potash, until no further precipitate ensues; then filter the solution, and wash the precipitate in water, and, when dry, make it into a paste with oil, and proceed as before.

* Distil muriatic acid from manganese: expose the mass to strong heat. When on washing some of it, prussiate of potash throws down a white precipitate, then dissolve and filter the whole mass, and throw it down by a solution of alkali. Filter: fuse with charcoal powder and oil in a crucible lined with charcoal. It requires a strong heat. The metal should be kept covered with alcohol. DAVY.

RATIONALE....The sulphuric acid unites to the potash, and forms sulphate of potash; and the tartareous acid joins to the manganese, and forms a tartrite of manganese, which is decomposable by heat.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF MANGANESE.

EXPERIMENT I.

Manganese becomes oxydated at the common temperature of the atmosphere.

IF pure manganese be reduced to small pieces, and exposed to the air, it tarnishes, and assumes a lilac colour, which soon changes to brown and black. The metal then crumbles into a violet-coloured powder, which changes blacker as the oxydation proceeds, and at last becomes the black oxyd of manganese. The oxydation is greatly accelerated by the assistance of heat.

EXPERIMENT II.

Formation of the white, or imperfect oxyd of manganese.

Take the residuum left in the retort after the disengagement of oxygenated muriatic acid gas, dilute it with distilled water, and filter it. Then decompose it by gradually adding a solution of potash, wash the precipitate and dry it. This is the white oxyd of manganese.

EXPERIMENT III.

Oxyd of manganese is soluble in sulphuric acid.

(Sulphate of manganese.)

Let six parts of concentrated sulphuric acid be poured upon one of pulverized black oxyd of manganese, and the mixture heated in a glass retort. A vast quantity of oxygen gas will be disengaged, and the residuum will be a hard white mass, which must be powdered and boiled in water. The fluid, when filtered, affords, on adding a little

sugar, a colourless solution, which by evaporation, yields large, transparent, quadrangular crystals, called *sulphate of manganese.*

REMARK....If the coloured solution of sulphate of manganese be exposed to the rays of the sun, it loses its colour, and regains it when removed into darkness.

RATIONALE....This depends on the de-oxydation of the metal by vivid light.

EXPERIMENT IV.

Manganese combines with phosphorus.

(Phosphuret of manganese.)

Manganese may be united to phosphorus by melting equal parts of this metal, and glacial acid of phosphorus, in a crucible, with one sixth part of charcoal powder.

Or, by dropping phosphorus upon red-hot manganese.

The phosphuret of manganese obtained in either of these processes is white, brittle, granulated, and of a metallic lustre. It is more fusible than manganese and unalterable by exposure to the air. When heated, the phosphorus burns, and the manganese becomes oxydated.*

EXPERIMENT V.

Alkalies unite with the perfect oxyd of manganese in the dry way.

These compounds possess the singular property of changing colour when dissolved in water: for instance, let one part of black oxyd of manganese, reduced to powder, and three parts of nitrate of potash, be exposed to ignition in a crucible, until the mixture fuses; when the mass assumes a dry earthy appearance, it is partly soluble in water. If a small portion of this powder be put into a glass, containing spring water, the fluid becomes green, then violet, next reddish, and at last totally colourless. This property, which has acquired to the compound the name of *mineral cameleon*, is destroyed by a very small quantity of sulphuret of potash.

RATIONALE....The nitrate of potash is decomposed, and the black oxyd of manganese is brought to the state

* It does not combine with sulphur, hydrogen, azot or carbon. DAVY.

of a more imperfect oxyd by the ignition: it then becomes partly soluble in the potash. This solution would appear blue; but as some portion of oxyd of iron is always contained in the black oxyd of manganese, its colour is changed to green by the yellow tint of the oxyded iron. This oxyd gradually subsides, and the blue colour appears. The oxyd of manganese now attracts more oxygen from the air, and assumes a reddish-brown tinge, which increases more and more, and at last becomes black. It is then precipitated, and the solution becomes limpid.

ANALYSIS OF ORES OF MANGANESE.

Ores of manganese always contain a variety of different earths; it is therefore advantageous to free them from these admixtures, by digesting them for some hours in diluted nitric acid, which has no effect upon the oxyd of manganese. This being done, let one part of the ore be digested in six or eight of concentrated muriatic acid, and assist the action by a gentle heat. Repeat this operation with half this quantity of acid, until no further solution takes place, which may be known by holding a piece of litmus paper over the fumes which arise from the evaporating vessel. If the blue colour of the litmus paper becomes reddened, this operation is at an end; but if its colour becomes discharged, the operation must be continued. The whole is then to be left undisturbed (the insoluble part which remains consists mostly of silex) and afterwards filtered. The muriatic solution must then be decomposed by letting fall into it a solution of carbonate of soda. A copious precipitate will instantly take place, which is of a white colour, but it soon becomes gray when left exposed to air; or black, when heated in a crucible. This is the oxyd of manganese contained in the ore.

For fuller accounts of ores of manganese, and the rest of metallic ores, earth, stones, &c. see Accum's Practical Essay on the Analysis of Minerals.

[Manganese is used in bleaching, to oxygenate the common muriatic acid. The best proportions are 3 parts common salt by weight, 2 parts oil of vitriol and $1\frac{1}{2}$ part manganese.

It is also used by potters for a black colour, and by glass makers in very small proportions to render glass colourless. Manganese tinges glass hyacinthine colour. T. C.]

NICKEL.

PART XLVII.

NATURAL HISTORY OF NICKEL.

IT is to Cronstedt that we are indebted for the discovery of this metal; though the substance from which he extracted it was known in the year 1694. Cronstedt proved it to be a peculiar metal in the year 1751. Nickel is found in nature generally in the metallic state, more rarely in that of an oxyd. Its ores have a coppery red colour, generally covered more or less with a greenish gray efflorescence. The most abundant ore is that termed *sulphuret of nickel* or *kupfernickel*, which is a compound of nickel, arsenic, sulphuret of iron, and sometimes cobalt and copper. This ore occurs either massive, or disseminated, but never crystallized; it is of a copper colour, sometimes yellowish, white, or gray. It exists also combined with oxygen and a little carbonic acid, in what is called *native oxyd of nickel, (nickel ochre)* it then has an earthy appearance, and is very friable: it is found coating *kupfernickel*, and seems to originate from the decomposition of this ore. It is found contaminated with iron in the meneral substance called *martial nickel:* this native combination, when fresh broken, has a lamellated texture; when exposed to the air, it soons turns black, and sometimes exhibits thin rhomboidal plates placed irregularly over each other. It is also found united to arsenic, cobalt, and alumine in the ore called *arseniate of nickel.*

PROPERTIES OF NICKEL.

Nickel, when free from hèterogeneous substances, is of a pale flesh colour. When fresh broken it has a strong lustre. It has a fine grained compact texture, and can be a little flattened by hammering, similar to cast iron. It leaves a trace when rubbed upon the polished surface of a hard stone. Its specific gravity is 7.330.* It requires a very intense heat for fusion. When exposed for a long time to a humid atmosphere, its surface becomes gradually covered with an oxyd of a greenish hue; this takes place likewise, and more rapidly, when heated in contact with air. When fused with borax it produces a glass of a hyacinth colour. It unites with phosphorus by fusion, and forms with it a phosphuret which is very fusible, white, and in brilliant needles. With sulphur it forms by fusion a hard yellow mass, with small brilliant facets. Sulphuric acid, assisted by heat, dissolves it. Nitric acid acts on it more rapidly. Muriatic acid, when heated on it, likewise dissolves part of it. Boracic and phosphoric acids seem to have little or no action on nickel. It readily unites with gold, and renders that metal white and brittle. It likewise fuses with platina, silver, and bismuth. It does not alloy with mercury. It is easily oxydated by the nitrate and the super-oxygenated muriate of potash. *It is not magnetic*, nor has it the smallest effect upon the magnetic needle. This has been proved by Mr. Chenevix, who has also shown that the magnetism of common nickel is owing to the iron which so obstinately adheres to it: for a portion of iron, *so small as not to be detected by the best chemical tests*, when combined with nickel, is capable of communicating magnetic properties to the whole mass as strong as if the whole were composed of steel.

METHOD OF OBTAINING NICKEL.

To obtain nickel, the ore is first roasted, in order to free it from sulphur and arsenic; it then is changed into a greenish oxyd. This oxyd is mixed with two or three parts

* 8.38, and when forged, 8.82. DAVY.
It combines with chlorine, sulphur, phosphorus, perhaps with carbon, but not with hydrogen, or azot. It is contained in all the known meteoreolites. It alloys with iron in all proportions. DAVY.

of black flux. The mixture is put into a crucible, and being covered with decripitated muriate of soda, it is brought to the state of fusion, by the strongest heat of a smith's forge.

When the crucible is broken, there is found at the bottom, under brown, blackish, and sometimes blue scoriæ, a button of a yellowish white colour, equal in weight to a tenth, a fifth, and even a half of the ore employed. This metal, however, is still far from being pure.

In order to purify it, the button obtained is again broken into small pieces, strongly heated, and then digested with its own weight of concentrated sulphuric acid, and distilled to dryness. The dry mass is dissolved in water and filtered. This solution, in general, deposits crystals of arsenic, and finally affords dark green crystals of sulphate of nickel. This sulphate is re-dissolved in water, and decomposed by carbonate of potash. The precipitate is dissolved in liquid ammonia; the blue solution leaves a residuum which is filtered off, and the filtered solution saturated with nitric acid. The nickel is then precipitated in the form of a grayish green powder, by carbonat of potash. From this oxyd the metallic nickel is obtainable by exposing it to heat, when made into a mass with oil and a little charcoal powder.

The nickel obtained in this manner was, until lately, considered as perfectly pure. It possesses, however, magnetic properties. It is therefore contaminated with iron.

In order to obtain this metal in a state of absolute purity, the following method of Chenevix must be had recourse to:

Take the native sulphuret of nickel, reduce it to powder, and roast it in contact with charcoal powder over a gentle fire. When no more fumes arise, pour then nitric acid over it, and dissolve it by heat in a Florence flask. Decant the solution, filter it through bibulous paper, and evaporate it to dryness in a glass bason. Dissolve the nitrate of nickel in a sufficient quantity of distilled water, and decompose it by the addition of the strongest liquid ammonia, taking care to add it in excess. The oxyd of nickel and cobalt will thus be redissolved; then let the solution stand undisturbed till a precipitate again ensues. The solution must then be eva-

porated; it becomes blue during this process, by the precipitation of the cobalt, which should be separated, and the evaporation be then continued to dryness: the residue will be pure oxyd of nickel.

In order to reduce this oxyd to the metallic state, let it be made into a paste with oil, mix it with about three parts of black flux, and put it into a crucible, covering it with borax and muriate of soda, and heat the crucible violently for an hour and a half in a forge; a button will then be obtained, which is *pure nickel.*

ANALYSIS OF ORES OF NICKEL.

The ore called kupfernickel may be analysed in the following manner: Let any quantity of the ore be reduced to a fine powder, digest and extract it with nitric acid, as long as this fluid will take up any of the ore. Then transfer the whole on a filter, and wash the residuum by pouring water over it repeatedly. This insoluble residue consists for the most part of sulphur; all the other substances which were contained in the ore are held in solution by the acid. In order to separate them, dilute the solution with water, a turbidness will ensue, and a white precipitate will gradually fall to the bottom. This is the arsenic which was contained in the ore; it may be collected on a filter. A solution of potash must then be added in excess, and the precipitate boiled for a few minutes. The arsenic and sulphur, part of which remained still in the solution, will thus become completely separated. The precipitate must then be dissolved in acetous acid. On adding to this solution liquid ammonia, in considerable excess, the iron becomes precipitated, and the cobalt and nickel are retained in the fluid. On evaporating this solution, the cobalt becomes precipitated, which must be separated; and on continuing the evaporation to dryness, the nickel which is contained in the ore is obtained.

The ore called *arseniate of nickel* requires a treatment a little different from this. One part of the powdered ore must first be boiled with three of potash, in six [illegible]ts of water, for at least an hour. The residuum must be washed, and then analysed in the manner stated before.

NICKOLINUM.

PART XLVIII.

NATURAL HISTORY OF NICKOLINUM.*

SINCE the printing of the preceding pages, a new metallic substance has been announced, by Dr. J. B. Richter, to which he has given the name of Nickolinum. This metal, according to Dr. Richter, exists in the cobalt ores of Saxony. The following are the words of the discoverer of this metal as I find them before me.† "I was chiefly surprised," says Dr. Richter, "that Nickel, after being purified from cobalt, iron, and arsenic, and after that reduced without the addition of a combustible body, never formed a mass, but was always found dispersed in small particles in a hard heavy mass, which had the appearance of the remains of vitrified copper.

"This hard matter had no metallic lustre, neither was it attracted by the magnet: its colour was of a blackish gray on the surface, with a small degree of brightness; and in powder it was brown, grayish and greenish.

"Some weeks ago I endeavoured to reduce *per se* almost half a pound of oxyd of nickel, which I had purified as well as possible by the liquid process, for the greatest part

* Neither Henry in the 6th edit. of his Chemistry, 1810, or Davy in his Elements of Chemical Philosophy, 1812, acknowledge this metalline substance. T. C.

† Annales de Chimie, LXIV. and Nicholson's Journal, No. 48. p. 261.

of a year, at a considerable expense: as this oxyd was not of a lively green, I thought this was caused by the "extractive matter" which might be in the potash employed for the precipitation of the sulphate of nickel from the ammoniacal preparation: it is true that this triple combination had not that beautiful grass-green colour which it commonly had; but I thought this might be caused by the substitution of the potash to the ammonia mixed with the copper, which could not be separated but by the reduction *per se*.

"From these ideas I hoped to have at least four ounces of perfectly pure nickel, but was disagreeably surprised by finding in the crucibles, which were deformed in the usual manner and perforated by the vitrified copper, a rough mass with the appearance I have before mentioned, and which contained only a morsel of about two and a half drachms, and consequently only five drachms of pure nickel in the two crucibles. I reduced to powder in an iron mortar the remaining mass (which could not be properly called scoriae) and separated from it, by the sieve and the magnet, the particles of nickel which it might contain, which produced near two and a half drachms more; and that nothing might be lost, I treated the powder with nitric acid, which attacked it vigorously at the first, and gave a solution of nickel, but after that did not act on it in the least, so that the powder was but little diminished in weight: in exposing this matter to reduction *per se*, it produced no regulus, but merely agglutinated its parts.

"Having again pulverized the mass, which weighed almost $4\frac{1}{2}$ ounces, I mixed with it one ounce of charcoal in powder, and exposed to the fire of a porcelain furnace during eighteen hours, in a crucible closed with a luted cover, in a part of the furnace which seemed to me to have most heat. After having broken the crucible, which was in a sound state, I found, under the scoria of a deep blackish-brown colour, a well fused button of metal which weighed two ounces and three quarters: it was not at all connected with the adjoining parts of the scoria, and had at its inferior part a particular shape, which was caused by cavities which were not produced by the crucible.

"This metal had the gray colour of steel, inclining a little to red: it presented in its fracture a grain not very

fine: it was rather hard; could be extended a little under the hammer in a cold state: heated to redness, it endured little the strokes of the hammer: it was attracted by the magnet, but not so strongly as either iron or nickel: it had many properties common to nickel, but it was distinguished from it entirely by others. As many of these properties were such that those not well acquainted with nickel in its perfectly pure state might take it for that metal, I have called it *Nickolinum*.

"The nickolinum was free from all the metals which are found in the cobalt ores, except a little copper.

"The specific gravity of cast nickolinum, which enters more readily into fusion than nickel, is 8.55: and of forged nickolinum 8.60. On putting it into nitric acid and heating it, it is attacked more quickly than nickel. I remember having observed an equally violent action of nitric acid on nickel reduced by charcoal, which I then considered as pure, and which I dissolved in order to precipitate from it by potash an oxyd, which I might reduce *per se*.

"The solution of the nickolinum went on well; being come to the point of saturation, it had a blackish-green colour, and assumed a gelatinous consistence.

"I employed my first care to separate from it a part of the iron which I thought it contained, and left it to dry a little over a spirit lamp: the mass became continually of a deeper green, and in approaching to dryness it gave out much red vapours, and the residue became of a blackish gray; I added distilled water to it, which dissolved but little of it, and that which was dissolved was an insignificant quantity of nickel.

"I poured muriatic acid on the blackish powder well washed, which gave a green solution, in disengaging a strong odour of oxygenated muriatic acid.

"The muriatic solution was, as well as the nitric solution, of a deep blackish grass-green colour: being evaporated to dryness, it produced a reddish mass, which became green in a moist air, and which communicated the green colour to water in which it was dissolved.

"This dark-coloured oxyd of nickolinum was insoluble in nitric acid, and in sulphuric acid; but if sugar or alcohol was added, the solution took place with facility at the boiling point.

"The sulphate of nickolinum, being combined with water, is also of a blackish green; but it assumes a pale red colour on being deprived of the water.

"If carbonate of potash be added to the preceding solutions of nickolinum, it occasions a precipitate of blue carbonate of nickolinum, inclining a little to gray and green, and of a pale tint: this combination is very light and soft, and dissolves in the acids with a strong effervescence. I remember to have had, some years ago, this precipitate of a bad colour, and not then to have examined it, considering it as a mixture of iron, nickel, and arsenic (which last continually made itself noticed by its odour of garlic) but at last I suspected its nature.

"If the solution of nickolinum is decomposed by caustic potash, it gives a precipitate which resembles in its colour carbonate of chrome; that is to say, it is of a deep greenish-blue, which does not change when it is washed: being dried with a gentle heat, it assumes a pale colour, which becomes deeper when it is moistened with water.

"If any of the foregoing solutions of nickolinum be mixed with ammonia to excess, the liquor assumes a pomegranate red colour, and remains transparent; which proves that it does not contain any iron, because that this latter is not soluble in ammonia. By candle-light this solution is with difficulty distinguished from that of perfectly pure nickel; but by day-light, this latter is of an amethyst red colour, as I have elsewhere remarked.

"I shall now compare the principal properties in which nickolinum resembles altogether, or in part, nickel or cobalt, and those in which it is distinct from them.

"It resembles cobalt

"1. By its property of super-saturating itself with oxygen at the expense of the nitric acid, and thus forming a body which resembles the black oxyd of manganese with regard to its solubility in the acids: 2. By its property of not being reducible but by the intervention of a combustible body.

"It differs from cobalt

"1. By the blackish-green colour of its solution, even when they are entirely neutralized. It is known that the neutral solutions of cobalt in the sulphuric, nitric, and muriatic acids, are of a crimson-red colour; and that the

muriate of cobalt alone becomes of a greenish-blue on being deprived of its water: from whence it happens that an excess of acid produces this colour, because it combines with the water. With the muriate of nickolinum precisely the reverse takes place; when mixed with water it is green (although of a less beautiful colour than the cobalt without water) and when deprived of its water it becomes reddish. 2. By the colour of its carbonate: that of cobalt is of a beautiful poppy blue, but the carbonate of nickolinum is a bluish green inclining to a pale gray. 3. By the colour of its oxyd precipitated without carbonic acid: that of cobalt is of a deep blue, and changes on washing to a blackish brown; but this oxyd of nickolinum is of a greenish blue, and its colour does not change.

"Nckolinum resembles nickel.

"1. By its strong magnetic quality; although this is not so great as that of nickel. 2. By its malleability, which however is less than that of nickel. 3. By the deep green of its solutions; although this colour is not so beautiful as that of the solutions of nickel. 4. By the loss of this green colour when its neutral combinations are deprived of water. 5. By the colour of the acid solution with an excess of ammonia, which cannot be well perceived by candle-light.

"Nickolinum differs very distinctly from nickel.

"1. Because it cannot be reduced without a combustible body added to it. 2. Because nitric acid attacks and oxydates it more easily, Nickel is not near so readily acted on by the nitric acid if it is not mixed with the nickolinum, which almost always happens with the magnetic nickel which is considered to be in a state of purity, and which has not been reduced *per se* before my discovery. 3. It also differs from nickel by the property first mentioned of those in which it resembles cobalt.—4. By the colour of its combinations with the acids, when deprived of water: this colour in nickel is almost a buff *(chamois)* and in nickolinum a reddish, except in the nitrate of nickolinum, which cannot be deprived of water without decomposing it. 5. By the colour of the precipitates, mentioned in the second and third articles concerning the properties wherein this new metal differs from cobalt, which are in those of nickel of a green

colour, entirely different from those of nickolinum, which latter are of a much more agreeable green, especially those of the carbonate."

Whether this substance will retain its place among the metals, must be left to future investigation; at present we have only the authority of Dr. Richter for inserting it.

COBALT.

PART XLIX.

SECT. I.

NATURAL HISTORY OF COBALT.

COBALT has never yet been found pure in nature. We meet with it almost always either in the state of an oxyd; alloyed with other metals in the form of a sulphuret; or combined with an acid.

Cobalt in the state of an oxyd forms the *black cobalt ore*. This ore is found in Germany, either in powder of a black or gray colour, or in compact masses. In the last form it exhibits at its fracture rose-coloured spots. There are several varieties of this ore.

Cobalt alloyed with other metals forms the *dull white cobalt ore*. In this ore, which continues either amorphous or crystallized, cobalt is united to iron and arsenic The colour of this ore when fresh broken is white or bluish-grey, sometimes with a shade of red. It has a metallic lustre. Its texture is compact. Cobalt united to sulphur forms the *white cobalt ore*. It is met with in masses or crystallized in cubes, dodecahedra, and octahedra. Its colour is a tin-white, sometimes reddish-yellow. Cobalt combined with arsenic acid forms the *red cobalt ore*, arseniate of cobalt. It is found in masses of various shapes. Its colour is red, inclining to orange.

PROPERTIES OF COBALT.

Cobalt when in a pure state is of a steel-gray colour, with a tinge of red, and a fine close grain. It has a granulated fracture, and is easily broken and pulverized. Its

specific weight is between 7.700 and 7.811. It requires a very intense heat for its fusion, nearly equal to that necessary to melt cast iron. When heated in contact with the air, it oxydates before fusion. Phosphorus renders it very fusible, and converts it into a phosphuret. It unites to sulphur with difficulty, but very well with the alkaline sulphurets by fusion. When alloyed with metals it renders them granulated, rigid and brittle. It is attacked by the greater number of the acids, and unites with the boracic acid. Its solutions in different acids become green when heated; and from this property it is used as an ink, which when written with on paper is invisible, but becomes visible when gently heated, and disappears when cold. It takes fire in oxygenated muriatic acid gas. It colours glass of a fine blue. It unites with platina, gold, iron, nickel, copper, and arsenic, by fusion; but silver, lead, bismuth, and mercury, refuse to unite with it in the dry way. In its purest state it is not only obedient to the magnet, but if we may trust to the accuracy of some experiments made by Kohl and Wenzel, it may even receive a magnetical attractive power.*

Nitrate of potash oxydates cobalt readily. It detonates by the blow of a hammer when mixed with oxygenated muriate of potash. It produces fine blue colours in procelain, enamels, artificial gems, &c.

METHOD OF OBTAINING COBALT.

The process made use of by chemists for obtaining cobalt is to torrefy the cobalt ore in an open fire, in order to separate from it the arsenic or sulphur. The cobalt is then obtained in the state of a black oxyd more or less dark. This oxyd must be mixed with three parts of black flux, and one of decrepitated muriate of soda; some add also half a part of resin. The whole is put into a crucible of such a capacity that at least one-third of it may remain empty, and placed in a furnace exposed to a gentle heat until the resin ceases to burn; the fire must then be raised gradually, in order to bring the crucible to a white heat, and in that state it must be kept until the matters are completely fused. It is then suffered to cool, and having broken the crucible, the cobalt must be separated from the scoriæ, which are of a blue colour.

* Crell's Neue Endeck, vol. VII. p. 39.

REMARK....It is impossible to obtain cobalt in this way in a state of considerable purity. It always is contaminated with iron.

In order to get rid of this, the cobalt previously oxydated is to be dissolved in nitric acid. The solution must then be evaporated to dryness, and the remainder exposed for some time to a red-heat, whereby the nitrated iron becomes decomposed: or the solution of cobalt in nitric acid may be precipitated by pure potash. The precipitate after being washed is dissolved in nitric acid. This solution must be evaporated to dryness, and re-dissolved in as little distilled water as possible, and then precipitated by liquid ammonia. More ammonia is then to be added, in order to re-dissolve the precipitate. This ammoniacal solution must be evaporated to dryness, and then mixed with two parts of black flux into a paste with a sufficient quantity of oil, and exposed to a white heat in a forge for at least two hours. A button will thus be obtained which is pure cobalt.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF COBALT.

EXPERIMENT I.

*Cobalt combines with phosphorus.**

(Phosphuret of cobalt.)

THIS may be accomplished by bringing the metal to a red heat in a crucible, and gradually adding phosphorus in small pieces. The compound is whitish and brittle. When exposed to the air it loses its metallic lustre. It is much more fusible than the pure metal. The phosphorus may be separated from it by heat, leaving the metal behind oxydated.

* It combines also with sulphur, wherein the sulphur is 28.5 per cent. It combines in at least two doses with oxygen, the black and blue oxyd. It has not been combined with hydrogen, azot, or carbon. Proust. DAVY.

Experiment II.

Cobalt decomposes nitric acid by the assistance of heat with great rapidity.

(Nitrate of cobalt.)

Put pounded cobalt into a Florence flask, and pour over it five or six times its weight of nitric acid; place the flask over a lamp, and heat it, till the metal is dissolved; leave the solution at rest, and then decant it. When the solution is at the point of saturation, it has a brown rose colour. Evaporate the solution in a glass bason till it is reduced to one-half; on cooling, it will form crystals in small needles, called nitrate of cobalt.

Experiment III.

Cobalt is soluble in muriatic acid.

(Muriate of cobalt, or green sympathetic ink.)

Put into a matrass one part of cobalt and four of nitric acid. Digest the mixture on a sand-bath for three or four hours, or until the solution be almost completed; then add muriate of soda equal in quantity to the cobalt employed, and four times as much water as nitric acid; filter the liquor through paper, and nitro-muriate of cobalt, or more properly muriate of cobalt, will be obtained.

If letters be traced on clean paper with this solution, they will be invisible: but by exposing the paper to a gentle heat, they will appear of a beautiful green: this colour will disappear as the paper cools, and may be made to appear and disappear successively.

Experiment IV.

Cobalt combines with acetic acid when in the state of an oxyd.

(Acetite of cobalt, or blue sympathetic ink.)

Though acetic acid does not act on cobalt in its metallic state, its oxyd is dissolved by it with moderate facility when assisted by heat. The solution of acetite of cobalt is

rose-red; it yields a *blue* sympathetic ink, and is best prepared in the following manner:

Take one ounce of cobalt reduced to powder, put it into a Florence flask, and pour over it two ounces of pure nitric acid. Expose the mixture to a gentle heat, and when the cobalt is dissolved, add, by small quantities, a solution of potash, until no more precipitate ensues. Let this precipitate subside, decant the super-natant fluid, and wash the residuum repeatedly in distilled water until it passes tasteless. Then dissolve it in a sufficient quantity of pure distilled vinegar, by the assistance of a gentle heat; taking care to have a saturated solution, which will be known by part of the precipitate remaining undissolved after the vinegar has been digested on it for some time. This fluid is a solution of oxyd of cobalt in acetic acid, and forms a beautiful blue sympathetic ink, by the addition of about one-eighth part of muriate of soda. This ink, like that made with the nitro-muriatic acid, is not visible without heat, and disappears when the paper grows cold.

Remark.....The cause of this singular change of the solutions of cobalt has not hitherto been explained in a satisfactory manner. It takes place equally in close vessels, so that it can scarcely be ascribed to the action of the air or of moisture. At present it is supposed (but without any direct proof) to be owing to the partial deoxydation of the oxyd of cobalt by heat, and its re-absorption of oxygen when cold.

These phenomena arrested particularly the attention of former chemists, and accordingly to their fanciful way they gave them the name of *sympathetic inks;* an appellation appropriated to all liquids; the characters of which are colourless and invisible when written on paper, but become visible and coloured by undergoing certain processes, and likewise to those which form characters upon paper susceptible of changing their colour by artificial methods.

ANALYSIS OF ORES OF COBALT.

Take one part of the ore previously comminuted in a mortar, pour over it in a Florence flask three ounces of dilute nitro-muriatic acid, and assist its action by heat;

repeat this operation two or three times, till nearly the whole of the ore is dissolved. Let the mixture stand undisturbed for a few hours, decant the super-natant fluid and filter it gradually. The insoluble residue consists of sulphur and silex. To the before obtained nitrous solution, carbonate of potash dissolved in water must be added as long as a cloudiness appears.

When no farther precipitate is produced, filter the whole, wash the precipitate which remains on the filter repeatedly, by pouring distilled water over it, and then dry it. The precipitate thus obtained consists of iron and cobalt. In order to separate these metals, let it again be dissolved in diluted nitric acid, and decompose this solution by adding liquid ammonia till no further cloudiness ensues; collect the precipitate and dissolve it in acetous acid, and suffer this solution to evaporate slowly. By this process the iron gradually becomes separated in the form of a yellow or red powder. The solution must therefore again be filtered. The filtered solution which contains the acetite of cobalt is now to be mingled with liquid ammonia, till the odour of the latter is predominant. The arsenic will then become separated, and the cobalt remains in solution. By then evaporating the ammoniacal solution, the cobalt will be obtained in the state of an oxyd. In order to reduce it to its metallic state, it may be mixed with two or three parts of black flux, and one of borax, and then exposed to a violent heat in a smith's forge, for at least one hour and a half.

URANIUM.

PART I.

NATURAL HISTORY OF URANIUM.

THIS metal was discovered by Klaproth in the year 1789. It exists combined with sulphur and a portion of iron, lead, and silex, in the mineral termed *Pechblende*, or *oxyd of uranium*. Combined with carbonic acid, it forms the *chalcolite*, or *green mica*: and mixt with oxyd of iron, it constitutes the *uranitic ochre*. It is always found in the state of an oxyd with a greater or smaller portion of iron, or mineralized with sulphur and copper. The ores of uranium are of a blackish colour, inclining to a dark iron, and of a moderate splendor; they are of a close texture, and when broken present a somewhat uneven, and in the smallest particles a conchoidal surface. They are found in the mines of Saxony.

PROPERTIES OF URANIUM.

Uranium exhibits a mass of small metallic globules, agglutinated together. Its colour is a deep gray on the outside, in the inside it is a pale brown. It is very porous, and is so soft that it may be scraped with a knife. It has but little lustre. Its specific gravity is 6.400. It is more difficult to be fused than even manganese. When intensely heated with phosphate of soda and ammonia, or glacial phosphoric acid, it fuses with them into a grass-green glass. With soda or borax it melts only into a gray, opaque, scoriaceous bead. It is soluble in sulphuric, nitric, and muriatic acids. It combines with sulphur and phosphorus, and alloys with mercury. It has not yet

been combined with other combustible bodies. It decomposes the nitric acid, and becomes converted into a yellow oxyd. The action of uranium alone upon water, &c. is still unknown, probably on account of its extreme scarcity.

METHOD OF OBTAINING URANIUM.

In order to obtain uranium, the *pechblende* is first freed from sulphur by heat, and cleared from the adhering impurities as carefully as possible. It is then digested in nitric acid; the metallic matter that it contains is thus completely dissolved, while part of the sulphur remains undissolved, and part of it is dissipated under the form of sulphurated hydrogen gas. The solution is then precipitated by a carbonated alkali. The precipitate has a lemon-yellow colour when it is pure. This yellow carbonate is made into a paste with oil, and exposed to a violent heat, bedded in a crucible containing and lined with charcoal.

Klaproth obtained a metallic globule 28 grains in weight, by forming a ball of 50 grains of the yellow carbonate with a little wax, and by exposing this ball in a crucible lined with charcoal to a heat equal to 170° of Wedgwood's pyrometer.

Richter obtained in a single experiment 100 grains of this metal which seemed to free from all admixture.

ANALYSIS OF ORES OF URANIUM.

These ores may be treated with nitric acid. In order to analyse the *black ore of uranium* or *pechblende*, let one part of the ore reduced to powder be digested in four or five of diluted nitric acid. Repeat this process two or three times. The undissolved residue is a mixture of the silex, sulphur, and iron, which was contained in the ore. To get rid of a small quantity of iron, which generally is taken up by the acid, immerse a polished plate of zinc in the solution. The iron will thus become precipitated. On evaporating the solution a precipitate ensues, which is nitrate of lead. The solution must then be filtered, and a solution of potash added, to throw down the zinc and uranium. The precipitate obbtained by means of this agent must be

transferred into a phial containing liquid ammonia, and suffered to stand for some days. The oxyd of zinc will by this means be dissolved, and the oxyd of uranium be left behind. It must therefore be separated on a filter, washed and dissolved in diluted sulphuric acid, and then evaporated slowly; it will yield crystals of a lemon-yellow colour.

The yellow oxyd of uranium, or *uranitid ochre*, may be treated in a similar manner with nitric acid. The uranium will be dissolved in the acid, and the iron left behind.

Green mica, or *chalcolite*, may be analysed by first dissolving it into nitric acid, and then adding to the solution liquid ammonia in excess. The oxyd of uranium will become precipitated, and the copper which was contained in the ore remain dissolved in the solution.

TITANIUM.

PART LI.

NATURAL HISTORY OF TITANIUM.

THIS is likewise a newly discovered metal. It was first noticed by Mr. Gregnor as existing in the state of an oxyd, mixed with iron, manganese, and silex, in a grayish black sand found in the vale of Manachan in Cornwall, and thence named *Menachanite*, or *oxyd of Titanium, combined with iron*. It has since been discovered by Klaproth, in an ore named *Titanite*,* or *oxyd of Titanium, combined with lime and silex*. This ore is generally met with crystallized in four-sided prisms, not longer than a quarter of an inch. Its colour is a yellowish red, or blackish brown; it is opaque, and of an imperfect lustre. It breaks with a foliated, uneven, or conchoidal fracture. It exists also in an ore called *Red schorl of Hungary*, or *red oxyd of Titanium*. This ore, which is found generally crystallized in rectangular prisms, is of a brownish red colour, and its texture foliated. In all these ores titanium exists in the state of an oxyd.

PROPERTIES OF TITANIUM.

Titanium has only been obtained in very small agglutinated grains. It is of a red-yellow and crystalline texture, brittle, and extremely refractory. Its specific gravity is about 4.2; when broken with a hammer while yet hot from its recent reduction, it shows a change of colours of purple, violet, and blue. In very intense heat it is volatilized. Most of the acids have a striking action on this metal. Nitric acid has little effect upon it. It is

* Titanite and Rutile are found with iron in many parts of Virginia. T. C.

very oxydable by the muriatic acid. It is not attacked by the alkalies. Nitro-muriatic acid converts it into a white powder. Sulphuric acid when boiled upon it is partly decomposed. It is one of the most infusible metals. It does not combine with sulphur, but it may be united to phosphorus.* It does not alloy with copper, lead, or arsenic; but combines with iron.

METHOD OF OBTAINING TITANIUM.

It is extremely difficult to reduce the oxyd of titanium to the metallic state. However, the experiments of Klaproth, Hecht, and Vanquelin, have proved its reducibility. According to the two latter, one part of the oxyd of titanium is to be melted with six of potash; the mass when cold is to be dissolved in water. A white precipitate will be formed, which is carbonate of titanium. This carbonate is then made into a paste with oil, and the mixture is put into a crucible filled with charcoal powder and a little alumine. The whole is then exposed for a few hours to the action of a strong heat. The metallic titanium will be found in a blackish puffed up substance possessing a metallic appearance.

ANALYSIS OF ORES OF TITANIUM.

Let the ore of titanium, reduced as usual to a fine powder, be fused with three times the quantity of potash or its carbonate. The melted mass is then to be dissolved in hot water. A white precipitate gradually separates, which is the white oxyd of titanium. This is all that is necessary to be done with that species of ore called *red schorl (oxyd of titanium.)* But when iron and silex are present, as is the case with the *menachanite*, the following method of Chenevix may be adopted.

Saturate an alkaline solution obtained as above with muriatic acid. White oxyd of titanium will thus become precipitated. Separate the precipitate by filtration; evaporate the solution to dryness in a glass bason, and redissolve the residuum in distilled water. The silex which

* Chenevix's paper in Nicholson's Journal, V. p. 134.

was contained in the ore remains behind. Precipitate the solution by an alkali; add the precipitate to the white oxyd obtained at first, and dissolve the whole in sulphuric acid. On adding to this solution phosphoric acid, the titanium will be precipitated, and the iron left behind.

The ore called *titanite*, which contains lime and no iron, must be fused with double or triple its quantity of potash, then dissolved in muriatic acid, and the silex separated as stated before. The titanium is then to be separated from the muriatic solution by adding ammonia to it; and afterwards from the lime by a solution of carbonate of potash..

COLUMBIUM.

PART LII.

NATURAL HISTORY OF COLUMBIUM.

TO the acidifiable metals, which have been some time known to the chemical world, we have to add one, of a more recent discovery, called Columbium, for which we are indebted to Mr. Hatchett, who discovered it in the year 1802* This accurate analyst, being engaged in examining and arranging some minerals in the British Museum, observed a specimen of ore which greatly resembled the Siberian cromate of iron. It appeared that the mineral in question was sent from the mines of Massachusetts in North America.

Mr. Hatchett describes this ore as being of a dark brownish gray externally, and more inclining to an iron gray internally; the longitudinal fracture, he found lamellated; and the cross fracture had a fine grain. Its lustre was vitreous, slightly inclining in some parts to metallic: moderately hard, and very brittle. The colour of the streak or powder was dark chocolate brown. The particles were not obedient to the magnet. Its specific gravity at a temperature of 65° Fahr. Mr. Hatchett found to be 5.918.

A series of accurate experiments made by its discoverer, prove that this ore consists of iron combined with a new metallic acid, which constitutes more than three-fourths of the whole.

The smallness of the quantity Mr. Hatchett had to operate upon has hitherto prevented us from seeing the metal in its metallic state; but the accuracy with which

* Philosoph. Transactions, 1802. Part I. p. 40. It is also said to be found in two Swedish minerals: the tantalite and stro tantalite by Ekeberg. It seems to me possible that Mr. Hatchett's specimen was a real chromat of iron. T. C.

the properties of its acid have been investigated, leave no doubt of its being different from any of the acidifiable metals hitherto known.

ANALYSIS OF THE ORE OF COLUMBIUM.

Mr. Hatchett analysed the columbate of iron in the following manner:

One part of the ore reduced to powder was mixt with five times its weight of carbonate of potash, and fused in a silver crucible. An effervescence took place during this process. When this had subsided, the whole was poured into a proper vessel and suffered to cool. Boiling distilled water was then poured upon it, and the whole was transferred upon a filter. The insoluble residuum was repeatedly washed in distilled water. The filtered fluid was now supersaturated with nitric acid. The result of which was, a white flocculent precipitate (columbic acid.)

The insoluble residue was again fused with carbonate of potash and treated as before, but scarcely any effect was thus produced; the alkali was therefore washed off, and the powder digested with muriatic acid, in order to get rid of the iron. The acid was then decanted, and the residuum washed in distilled water. It was again fused with carbonate of potash, dissolved, and precipitated with nitric acid. The residuum was repeatedly treated in a similar manner, till the whole was completely decomposed.

The muriatic solution was decomposed by ammonia. A copious ochreaceous precipitate was obtained, which was dissolved in cold diluted nitric acid. A small quantity of a white insoluble substance, similar to that which was obtained from the alkaline solution, was separated during this process. From this nitric solution Mr. Hatchett obtained, by means of ammonia, a precipitate of oxyd of iron.

The different alkaline solutions which had been made subsequent to that which has been first mentioned were mixed together, and being super-saturated with nitric acid, yielded the same white insoluble precipitate. The fluid from which this precipitate had been separated by nitric acid was then saturated with ammonia, and being boiled afforded about two grains of oxyd of iron.

200 grains of the ore, thus analysed, yielded to Mr. Hatchett

42 of oxyd of iron, and

155 columbic acid, the properties of which will be noticed under that article.

Such were the products obtained in the analysis; but as Mr. Hatchett was confined to experiment upon a small quantity of this ore, and could not repeat his researches, without destroying the remaining part of the only specimen at present known, he does not wish the above stated proportions of the component parts of the ore to be considered as absolutely exact.

CHROME.

PART LIII.

NATURAL HISTORY OF CHROME.

THIS metal, which is extremely scarce, and exists only in the state of a metallic oxyd, was discovered by Vauquelin. He found it in an ore called red lead ore of Siberia, or *chromate of lead.* The colour of this ore is red with a shade of yellow; when reduced to powder it is of a bright orange. Chrome has likewise been found in combination with iron, alumine, and silex *(chromate of iron and alumine)* in the department of Var in France.* It is met with in irregular masses. Its colour is brown; it has very little metallic lustre. Pontier† has lately found chrome combined with iron *(Chromate of iron)* in a quarry near Gussin, in the road to Cavalaire. It sometimes forms large masses. The emerald of Peru and spinel ruby owe their colours to this metal.

PROPERTIES OF CHROME.

Chrome is obtained in small agglutinated masses of a white colour inclining to yellow; it is very hard, extremely brittle and refractory, and crystallizes into needles.

Exposed to the heat of a blow-pipe it is covered with a lilac coloured crust, which becomes green on cooling. Heated by the same apparatus with borax, it does not melt; but a part, after being oxydated, is dissolved in this salt, and communicates to it a very beautiful green colour. Acids have only a weak action on this metal. The nitric is the only acid which produces any remarkable change;

* In Chester county, Pennsylvania, and at the Bare Hills, about 8 miles from Baltimore. It probably accompanies the soap stone stratum connected with the primitive range from Rhode Island to Virginia. T. C.

† Bulletin de Sciences, No. LVII.

it converts it into oxyd. It is capable of combining with three different portions of oxygen, and forming three different oxyds. It has not yet been combined with any combustible body. It does not appear to decompose water. It is unalterable by the alkalies. The other properties of this metal are not yet ascertained, neither are its uses known; perhaps it may afford beautiful and durable colours to the painter or the enameller.

METHOD OF OBTAINING CHROME.

Chrome is obtained from its native combinations by decomposing them by the alkaline carbonates, precipitating the chromic acid, and heating it strongly in a crucible.

The following method is recommended by Vauquelin. Seventy-two parts of chromic acid (the preparation of which shall be noticed immediately) are to be introduced into a charcoal crucible placed within another of porcelain filled with charcoal dust. The apparatus is then to be put into a furnace, and subjected to a very stong heat. Metallic chrome will then be found in the charcoal crucible. From seventy-two parts, Vauquelin obtained forty-three of metal.

ANALYSIS OF ORES OF CHROME.

The *red lead ore of Siberia*, or *chromate of lead*, may be analysed by boiling one part of the ore reduced to a fine powder, with three of carbonate of potash, in six or eight parts of water. The acid of chrome contained in the ore combines by this means with the potash, and the carbonic acid of the latter unites to the lead, and forms an insoluble compound (carbonate of lead.) In order to ascertain its quantity, put it into a flask, and dissolve it by heat, in nitric acid. On letting sulphuric acid fall into this solution, sulphate of lead will be formed, which may be decomposed by ignition with soda.

Or the chromate of lead may be treated with muriatic acid; in that case, muriate of lead precipitates, and the chromic acid remains in solution. This process must be repeated until the whole of the ore is decomposed. The solution then contains chromic acid, mixed with a little muriatic acid. From the latter it may be freed by drop-

ping into it a solution of nitrate of silver. Muriate of silver will be formed, which, when collected on a filter and dried, may be reduced to the metallic state by fusing it with double its weight of soda.

The *chromate of iron* may be analysed in the following manner; Let one part of the ore, mixed with eight times its weight of potash, be fused in a crucible for at least one hour. Pour the mass into a convenient vessel, and when cold boil it in a sufficient quantity of water for a quarter of an hour, and filter it. The residue which remains on the filter must be transferred into muriatic acid, and digested for a few minutes. The acid is then to be separated by filtration, and the residue treated as before, alternately with potash and muriatic acid until the whole is dissolved. The alkaline solutions must then be added together, and the same must be done with the acid ones. The first solutions contain the chromic acid of the ore, and the latter the iron, together with a little chromic acid. In order to free it from it, a solution of carbonate of potash may be dropt into it, and the precipitate boiled for a few minutes in a solution of potash. What remains is pure oxyd of iron. The chromic solution must now be saturated by gradually adding nitric acid, and then be decomposed by adding nitrate of lead. The precipitate which ensues is chromate of lead: 100 parts of it indicate 35 of chromic acid.

[The chromate of lead is a very fine yellow paint, which if not exposed to the sun, and if mixed with good varnish stands very well. T. C.]

MOLYBDENA.

PART LIV.

NATURAL HISTORY OF MOLYBDENA.

MOLYBDENA exists mineralized by sulphur in the ore called *sulphuret of Molybdena.* The ore, which is likewise scarce, is so similar in several of its properties to plumbago, that they were long considered as varieties of the same substance. It is of a light lead gray colour; its surface is smooth, and feels unctuous: its texture is lamellated; it soils the fingers, and marks paper bluish-black, or silver-gray. It may be cut with a knife. It is generally found in compact masses; seldom in particles, or crystallized. It is met with in Sweden, Spain, Saxony, Siberia, and Iceland.* Scheele showed that a peculiar metallic acid might be obtained from it; and later chemists have succeeded in reducing this acid to the metallic state. We are indebted to Mr. Hatchett for a full and accurate analysis of this ore.†

The native *sulphuret of molybdena* is the only ore hitherto known which contains this metal.

PROPERTIES OF MOLYBDENA.

Molybdena is either in an agglutinated blackish friable mass, having little metallic brilliancy, or in black powder. The mass slightly united shows by a magnifying

* And in quartz rock in Chester county, Pennsylvania. T. C.

† See his valuable paper on the analysis of the Carinthian Molybdate of Lead. Phil. Trans. 1796.

glass small round brilliant grains. Its weight is from 6.600 to 7.500. It is one of the most infusible of the metals. It is capable of combining with a number of metals by fusion. It forms with sulphur an artificial sulphuret of molybdena analogous to its ore. It unites also with phosphorus. The affinity of molybdena for oxygen is very feeble, according to Mr. Hatchett. The alkalies have no action on molybdena in the moist way, but it enters readily into fusion with potash and soda. It is oxydable by boiling sulphuric acid, and acidifiable by the nitric acid. Muriatic acid does not act upon it. It is capable of existing in not less than four different degrees of oxygenation.

METHOD OF OBTAINING MOLYBDENA.

To obtain molybdena is a task of the utmost difficulty. Few chemists have succeeded in producing this metal, on account of its great infusibility. The method recommended in general is the following: Molybdic acid is to be formed into a paste with oil, dried at the fire, and then exposed to a violent heat in a crucible lined with charcoal. By this means the oxyd becomes decomposed; a black agglutinated substance is obtained very brittle under the finger, and having a metallic brilliancy. This is the metal called molybdena.

ANALYSIS OF ORES OF MOLYBDENA.

Take one part of the ore reduced to powder, put it into a tubulated retort, containing three parts of nitric acid, adapt a receiver, and distil till no more drops fall from the neck of the retort. Having done this, pour again two ounces of nitric acid upon the ore in the retort, stir it well together with a glass rod, and repeat the distillation as before. This treatment must be repeated till the whole of the ore is converted into a white powder.

This powder, after being well washed in distilled water, is molybdic acid. The water used for the ablution of this acid must then be mingled gradually with small quantities of a solution of potash; by this means an additional portion of white precipitate will be obtained,

which after being washed may be added to the first. This being saparated, muriate of barytes is to be added to the fluid as long as any precipitate ensues; 100 parts of this precipitate indicate 14.5 of sulphur. The quantity of sulphur, as well as that of molybdena, may thus be ascertained.

The sulphuret of molybdena may likewise be analysed by mixing one part of the ore with four of nitrate of potash, and detonating the mixture, by transferring it in small quantities into a crucible kept red hot in a fire. The product must then be dissolved in water, and saturated with nitric acid. The precipitate which is obtained, after being washed, is molybdic acid.

The first process, however, is preferred.

TUNGSTEN.

PART LV.

NATURAL HISTORY OF TUNGSTEN.

THIS metal, which is never found but in combination, is by no means common. The substance known to mineralogists under the name of tungsten was, after some time, discovered to consist of lime, combined with a peculiar acid or metallic oxyd. This ore is now called *tungstate of lime*, and is exceedingly scarce. It has been found in Sweden and Germany, both in masses and crystallized, of a yellowish white, or gray colour. It has a sparry appearance, is shining, of a lamellated texture, and semi-transparent. The same metallic acid is likewise found united to iron and manganese; it then forms the ore called Wolfram, or *tungstate of iron and manganese*. This ore occurs both massive and crystallized, and is found in Cornwall, Germany, France, and Spain. Its colour is brownish black, and its texture foliated. It has a metallic lustre, and a lamellated texture; it is brittle, and very heavy; it is found in solid masses in the state of layers interspersed with quartz. These two substances are therefore ores of the same metal.

PROPERTIES OF TUNGSTEN.

Tungsten appears of a steel-gray colour. Its specific gravity is about 17.6. It is one of the hardest metals, but it is exceedingly brittle; and is said to be almost as infusible as platina. Heated in the air it becomes con-

verted into a yellow pulverulent oxyd, which becomes blue by a strong heat, or when exposed to light. Tungsten combines with phosphorus and sulphur, and with silver, copper, iron, lead, tin, antimony, and bismuth; but it does not unite with gold and platina. It is not attacked by the sulphuric, nitric, or muriatic acids; nitro-muriatic acid acts upon it very slightly. It is oxydable and acidifiable by the nitrates and super-oxygenated muriates. It colours the vitrified earth, or the vitreous fluxes, of a blue or brown colour. It is not known what its action will be on water and different oxyds. Its action on the alkalies is likewise unknown. It is not employed yet, but promises real utility, on account of its colouring property, as a basis for pigment, since the compounds it is said to form with vegetable colouring matters afford colours so permanent as not to be acted on by the most concentrated oxygenated muriatic acid, the great enemy of vegetable colours.

METHODS OF OBTAINING TUNGSTEN.

The method of obtaining metallic tungsten is a problem in chemistry. Scheele, Bergman, and Gmelin, did not succeed in their attempts to procure it. Klaproth* tried to reduce the yellow oxyd of this metal with a variety of combustible substances, but without success. Messrs. Ruprecht and Tondy† say, they have obtained this metal by using combustible substances alone, and by a mixture of combustible and alkaline matter.

The following process is recommended by Richter, an ingenious German chemist.‡

Let equal parts of tungstic acid and dried blood be exposed for some time to a red heat in a crucible; press the black powder which is formed into another smaller crucible, and expose it again to a violent heat in a forge for at least an hour. Tungsten will then be found, according to this chemist, in its metallic state in the crucible.

Remark....This author very properly objects to the use of alkalies or alkaline salts in this process, as they are

* Crell's Annal, 1786; vol. II. p. 502.
† Ann. de Chim. tom. VIII. p. 4.
‡ Richter uber die Neuen Gegenstande der Chemie, 1 Stuck, p. 49.

apt to form neutral salts with the tungstic acid, and in this way prevent its reduction. From the facility however with which Ruprecht and Richter seem to have obtained this metal, it may fairly be questioned whether it was entirely free from all admixtures.

The existence of metallic tungsten being doubtful, we must content ourselves with examining the properties of this substance in the state of an oxyd, for which we refer the reader to the article *Tungstic acid*.

The same must be the case with those metals which possess few metallic properties, or whose scarcity has hitherto prevented chemists from experimenting upon them; when a sufficient quantity of the ores can be procured, their characters and properties will no doubt be investigated. Hitherto chemists have paid attention to them when in combination with oxygen, or when they are brought to the state of an acid; we are consequently unable to say much about their metallic properties in the present state of our knowledge.

We are inclined to believe, with Mr. Hatchett,* that the time is perhaps not very far distant, when some of the newly discovered metals, which are now considered as simple, primitive, and distinct bodies, will be found to be compounds; but until that happens we are obliged to consider them as substances *sui generis*.

ANALYSIS OF ORES OF TUNGSTEN.

Tungstate of lime may be treated (like ores of arsenic) repeatedly with nitro-muriatic acid, till every thing soluble is taken up. The tungsten will thus be converted into a yellow oxyd, distinguishable from the oxyd of uranium, by its becoming white on the addition of liquid ammonia. The alumine which was contained in the ore may be separated by adding to the acid solution some carbonate of ammonia.

Ores of wolfram may be analysed in the following manner. Take one part of the ore, reduce it to a powder, and digest it for at least an hour, in four or five parts of muriatic acid; decant the acid, wash the residue in distilled water, and pour over it two parts of liquid ammo-

* Nicholson's Journal, July, 1802, p. 179.

nia; suffer it to stand for a few days, taking care to agitate it frequently. Then decant the ammonia, digest the residue again, alternately in muriatic acid and ammonia till the whole is dissolved. Evaporate the ammoniacal solutions in a glass basin to dryness, transfer the dry mass into a Wedgwood's crucible, and ignite it strongly. The product thus obtained is the yellow oxyd of tungsten.

The muriatic solutions may then be likewise added together, and mingled with one-sixth part of sulphuric acid, evaporated to dryness, and re-dissolved in water: on adding a solution of carbonate of potash a precipitate will be obtained, which consists of the iron and manganese contained in the ore. It may therefore be digested in acetous acid; the manganese will then become dissolved, and the iron remain behind. Finally, on adding an alkali the manganese will be precipitated, and the analysis will be complete.

ARSENIC.

PART LVI.

SECT. I

NATURAL HISTORY OF ARSENIC.

ARSENIC is scattered in great abundance over the mineral kingdom. It is found in black heavy masses of little brilliancy, called *native arsenic* (testaceous arsenic.) It is found in different parts of Germany. Mineralized by sulphur, it forms *sulphurized arsenic*, or *orpiment*.

This mineral is met with in Italy, about Mount Vesuvius. There are two varieties of this ore which differ from each other in colour, occasioned by the different proportions of its component parts. The one is called yellow *sulphurized arsenic*, or *orpiment*; the other, red *sulphurized arsenic*, or *realgar (ruby arsenic)* both are met with in Hungary and different parts of Germany. The colour of the first ore is a lemon yellow, inclining sometimes to a green: the colour of the latter is a ruby red; it is more transparent than the former, and found in compact solid masses, sometimes crystallized in bright needles. Arsenic united to oxygen constitutes the ore called *native oxyd of arsenic*. This ore is scarce; it is generally found of an earthy appearance, or as an efflorescence, coating native or metallic arsenic; its colour is a whitish-gray; it is rarely met with crystallized. Arsenic exists likewise alloyed with cobalt, antimony, tin, copper, lead, and various other metals.

PROPERTIES OF ARSENIC.

Arsenic is a brittle metal, and in the recent fracture of a lively bright colour, between tin-white and lead-

gray; but on exposure to the air it soon loses its metallic lustre, and turns prismatic, dull, and at last black. Its specific gravity is between 8.310 and 8.763, according to its texture. Its hardness surpasses that of copper; but its ductility is so little, and its brittleness so great, that it is readily converted into a powder by the hammer. It is entirely volatilized when heated to 356° Fahr. It sublimes in close vessels, and then crystallizes in tetrahedra, or octahedra. When heated with the access of air, it emits a strong smell of garlic, and burns with a bluish white flame. It combines with sulphur by fusion. It unites to phosphorus and combines with most of the metals. It gives a white colour to copper, and renders many of the ductile metals brittle. When mixed with hyper-oxygenated muriate of potash, it detonates strongly by the stroke of a hammer. It is soluble in hydrogen gas by heat. It does not decompose water alone. It decomposes sulphuric acid by heat. The nitric and nitrous acids oxydate it rapidly. The muriatic acid attacks it with heat. The oxygenated muriatic acid, when in a gazeous state, inflames it instantly. It is nearly unalterable by the fluoric, boracic, phosphoric, and carbonic acids. It unites with alcaline sulphurets and hydro-sulphurets. It is a deadly poison.

METHOD OF OBTAINING ARSENIC.

In order to obtain metallic arsenic, mix two parts of the white arsenic of commerce with one of black flux (obtained by detonating one part of nitrate of potash with two of acidulous tartrite of potash) and put the mixture into a crucible or melting pot. Invert over this another crucible, lute the two together with a little clay and sand, and apply gradually a red heat to the lower one. The oxyd of arsenic will be reduced, (metallized) and be found lining the upper crucible in small crystals of a metallic brilliancy.

RATIONALE....The charcoal of the black flux takes the oxygen from the white oxyd, and forms carbonic acid gas; which flies off during the process, and the oxyd becomes reduced to the metallic state. This reduc-

tion of the acid is greatly facilitated by the alkali of the flux.

REMARK....In order to obtain arsenic in a state of absolute purity, the metal before obtained must be reduced to powder, dissolved by heat in nitro-muriatic acid, and then precipitated by immersing into the solution a plate of zinc. The arsenic is thus precipitated in a fine powder, and may be reduced to its metallic state by exposing it in a covered crucible to a moderate heat.

If it be kept under water its metallic brilliancy may be preserved. This effect is still better produced by alcohol.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF ARSENIC.

EXPERIMENT I.

Arsenic burns and is volatilized by heat.

INTRODUCE into a crucible, made red hot in a coal fire, a small quantity of arsenic; it will soon begin to burn and become volatilized.

If this crucible be covered with another, and the joinings luted with a little clay, the arsenic will be found in the upper one in brilliant crystals.

EXPERIMENT II.

Arsenic stains copper white.

Insert a little arsenic, reduced to fine powder, between two polished plates of copper; bind them closely together with iron wire, and heat them. The inner surfaces of the copper plates will be rendered white by the arsenic.

The union of arsenic with copper may likewise be effected by fusing one part of arsenic and four of copper, in a common crucible. The alloy produced is a white metal.

REMARK....It is necessary in this experiment to cover the substances in the crucible with common salt, to prevent the action of the air.

Experiment III.

Arsenic decomposes sulphuric acid.

Put into a retort one part of arsenic reduced to a fine powder, and three of sulphuric acid; direct the neck of the retort under a receiver filled with mercury, in the mercurial pneumatic trough, and apply the heat of a lamp. When the mixture has boiled some time, sulphureous acid gas will pass into the receiver.

Rationale....The arsenic subtracts the oxygen of part of the sulphuric acid, which becomes converted into sulphureous acid gas. The oxyd of arsenic which is produced is dissolved in the other part of the acid.

Experiment IV.

Arsenic combines readily with sulphur.

If one part of arsenic and four or five of sulphur be hastily fused together in a well-closed crucible, the two substances unite and form a yellow compound, called sulphuret of arsenic.*

Experiment V.

Arsenic combines with phosphorus.

Put equal quantities of arsenic, reduced to powder, and phosphorus, into a Florence flask; pour water upon them, so as to cover them an inch, and apply the gentle heat of a lamp. The arsenic and phosphorus will unite, and form a phosphuret of that metal.

This combination may likewise be conveniently effected by gently heating, in a close phial, equal parts of phosphorus and pulverized arsenic.

Experiment VI.

Tin and arsenic may be alloyed by fusion.

Put into a crucible placed in a fire seven parts of tin, and one of arsenic: melt the mixture, and when completely united pour it out into an ingot. The alloy obtained will be found to be of a white colour; it is much harder, more sonorous, and less fusible than tin.

* Yellow arsenic, yellow orpiment, red arsenic, Realgar, are native combinations of arsenic with sulphur. T. C.
Arsenic has not been combined with azot or carbon. Davy.

Experiment VII.

Arsenic detonates with hyper-oxygenated muriate of potash by percussion.

Put a few grains of arsenic in contact with hyper-oxygenated muriate of potash, on an anvil or any smooth solid surface, and give it a smart blow with a hammer. The mixture will explode with a loud report.

The spontaneous accension of arsenic in oxygenated muriatic acid gas has been exemplified already.

ANALYSIS OF ORES OF ARSENIC.

Take any quantity of the ore, reduce it to powder, and introduce it into a Florence flask; pour over it three times its own weight of nitro-muriatic acid, composed of one part of nitric, and one and a half of muriatic acid; assist the action of the acid by the heat of a lamp or candle. When no further action ensues, if the ore is not completely dissolved, add a fresh quantity of acid, and proceed as before till all is dissolved. Then let the solution subside (for if the arsenical ore contained silver, a white heavy precipitate will be formed during the process) filter it, and evaporate it in a Wedgwood's bason to at least one-fourth. When so far concentrated, add distilled water to the solution, so long as it occasions any turbidness, which may be known by filtering, from time to time, a small quantity of the mixture, and assaying the filtered fluid by a fresh addition of water. The white precipitate, which is thus obtained, is the quantity of arsenic which was contained in the ore. In order to reduce it to the metallic state it may be re-dissolved in muriatic acid, and precipitated by immersing into this solution a plate of zinc, mixing with it at the same time a tenth part of alcohol.

If the ore contained silver, the white precipitate mentioned before must be dried, and then mixed with double its weight of carbonate of soda freed from its water of crystallization, and exposed in a crucible to a white heat for at least half an hour. The silver will be found at the bottom of the crucible in a metallic state.

The sulphurated ores of arsenic may be analysed in a similar manner, by treating them with nitro-muriatic acid. In this case an addition of acid will not dissolve the residue. The arsenic may be separated, by first concentrating the solution, and then adding to it water. The sulphur may then be collected on a filter, and dried between bibulous paper in a heat not above that of boiling water. If it be pure sulphur, it may be volatilized by a continued gentle heat.

TANTALIUM.

PART LVII.

NATURAL HISTORY OF TANTALIUM.

THIS metal exists in the mineral called Gadolinite, and also in a species of tin ore, or oxyd of tin (zingraupen.) In the first of these minerals, tantalium exists combined with oxyd of iron and manganese; in the latter it is united to *yttria*; hence the discoverer of this metal has called the latter mineral *yttro-tantalium*. Both are found in considerable abundance in Sweden and Finland.

PROPERTIES OF TANTALIUM.

Tantalium is distinguished from all other metals by being insoluble in any of the acids. It is acted on only by alkalies. The solution is decomposable by a copious addition of acids in excess. The product obtained is of a white colour, which it retains after having been ignited. Its specific gravity is 6.500. It fuses with phosphate of soda and ammonia, or sub-borate of soda, into a colourless glass. Exposed to a high temperature with charcoal, it agglutinates, and acquires a metallic aspect. Its fracture is brilliant, and its colour grayish black.

These properties, together with its great specific weight, have induced Mr. Ekeberg to consider it as a new metal.

The substances with which it might be confounded are the oxyds of tin, tungsten, and titanium; all of which are

more or less soluble in alkalies, and under certain circumstances resist the action of acids. But it is well known that the oxyd of tin is easily reducible, whereas the oxyd of tantalium requires an intense heat to reduce it even imperfectly. The oxyd of tungsten is soluble in ammonia, but that of tantalium is not. The colour communicated of phosphate of soda and ammonia by fusion with the oxyd of titanium is yellow or hyacinth colour, and that of the oxyd of tungsten is blue; but oxyd of tantalium fuses with these salts into a colourless glass.

CERIUM.

PART LVIII.

SECT. I.

NATURAL HISTORY OF CERIUM.

THIS metal has been lately discovered by Messrs. Bergelius and Heisinger of Stockholm, in a mineral from Bastnas, in Sweden, which had been supposed to be an ore of tungsten. This discovery has been since confirmed by the unquestionable testimony of Vauquelin, who, after a careful examination of the mineral, concurs in opinion that it contains the oxyd of an unknown metal. From the planet Ceres, discovered about the same period, it has been called cerium, and the mineral that contains it is termed cerite.

The tungsten of Bastnas, which is now called *cerite*, was found in the year 1750, in a copper-mine called Bastnas, or Saint-Gorans Koppargrufva, at Riddare-Hyltan, in Westmannia, of which, with asbestos, it formed the matrix: but after this time it was imbedded in quartz and mica, to the depth of seventeen toises.

The tungsten is almost always mechanically mixed with hornblende, striated actinote, of a clear green colour, (shorl) mica, sulphuretted copper, bismuth, and sulphuret of molybdena. The cerite powder is transparent, of a flesh colour, seldom yellow. In a mass the stone is of an irregular form. Its fracture is indeterminate, compact, and a little brilliant, with obtuse edges; it gives fire with steel but with difficulty. It does not scratch glass. It is not attracted by the magnet. It loses its hardness on being ignited, and also 6 or 7 per cent. of its weight. By this operation it becomes friable, and acquires a bright yellow colour. It does not melt alone.

PROPERTIES OF CERIUM.

Cerium appears to be susceptible of two degrees of oxydation. The alkalies precipitate a white oxyd from its solutions, which shows of a yellowish colour in the air, but, when perfectly dried, becomes dark. Exposed to a brisk and long continued fire, it takes a deep brick-colour. The oxalate and acetate of cerium, calcined in vessels not completely closed, yield a white oxyd, which, in an open fire, becomes of the colour of bricks. It does not melt by itself.

Treated with borax by the blow-pipe, it melts readily and swells. The globule heated by the exterior flame assumes the colour of blood; which, by cooling, passes to a yellowish green, and at length becomes colourless, and perfectly transparent. Melted by the interior flame, these changes do not take place; it is then reduced into a colourless glass; but exposed for a short time in the exterior flame, the same phenomena are produced. If too much oxyd of cerium is made use of, the glass resembles an opaque yellowish enamel. These changes are more easily manifested with the phosphate of soda and ammonia. If two clear and colourless globules are melted together, one of which was prepared with borax, and the other with the phosphate, they form a transparent glass, which, on cooling, becomes opaque and pearl coloured.

These characters, taken together, sufficiently distinguish the oxyd of cerium from the oxyd of iron. The latter also offers the same changes of colour; but its glass, on cooling, has a deep green colour, *which fades*. The globules made with borax and the phosphate melted together yield an opaque glass, the colour of which is a little deeper.

When oxyd of cerium is digested with sulphuric acid, these two substances unite, and the result is a red insoluble salt, which is sulphate of cerium at a *maximum of oxydation*. If the acid is concentrated, it scarcely dissolves any of it. If it is diluted with half its quantity of water, or a little more, the result is a yellowish oily liquor, which does not adhere to the glass, nor does it wet it. If the acid is mixed with six or seven times its quantity, or even more, of water, and employed in a sufficient quan-

tity, the oxyd is dissolved of an orange colour. By a slight evaporation of this solution, it yields small, prismatic, coherent crystals, of the colour of gold. This salt is an acidulous sulphate of cerium at a *maximum*. These crystals, thoroughly dried between blotting-paper, and exposed to the air, are gradually reduced to a yellow, almost crystalline powder. Re-dissolved in water, they experience a decomposition; white powder is deposited, and the solution becomes colourless. This white powder is a sulphate of cerium, but little oxygenated. If the solution is evaporated to dryness, it gives an acidulous sulphate of cerium still less oxygenated. These crystals are seldom cubical, but almost always prismatic, striated and collected in bundles. Their taste is sour, but they afterwards become saccharine and astringent.

Treated with muriatic acid, the yellow acidulous sulphate of cerium yields part of its oxygen to the acid, which is volatilized in oxygenated muriatic acid gas. The salt remains colourless. An augmentation of temperature alone is sufficient for the yellow acidulous sulphate of cerium to lose its colour, by losing the excess of its oxygen. If the heat is increased still more, the surplus of the acid is carried off, and a saturated sulphate of cerium remains. By a continued calcination, it regains oxygen, becomes red, and yields a sulphate of cerium at a *maximum*. The sulphate of cerium, disoxygenated by the muriatic acid, is more difficult to reoxydate by calcination.

In the humid way, the alkalies only decompose the sulphate of cerium incompletely. Ammonia precipitates an oxyd from the acidulous sulphate of cerium, which is only in a small quantity, but nevertheless contains part of the sulphuric acid. The sulphate of cerium is not perfectly decomposed, except by calcination with three times its weight of carbonate of soda or potash. The calcined oxyd is of a brown colour. By digestion, ammonia can deprive it of part of its acid: the oxyd takes a distinct flesh colour, which becomes brighter by drying. Digested with concentrated muriatic acid, or with nitric acid, a small quantity dissolves, having its yellow colour.

If a solution of acidulous sulphate of cerium is precipitated by potash, a triple combination of cerium, sulphuric acid, and potash, is separated, before the acid is

saturated. If too much potash is added, the combination is partly destroyed. The sulphate of cerium and potash, at a *maximum*, is of an orange colour; that which is at a *minimum*, is white. A similar combination is also obtained by pouring muriate of cerium into a solution of sulphate of potash. Sulphate of ammonia does not form any precipitate in it; but on adding a calcareous salt to it, sulphate of cerium combined with potash is rapidly deposited.

These characters offer a ready method of separating the sulphate of cerium from iron. It must however, be observed, that when the solutions are saturated, a little iron is also deposited, which gives a yellow colour to the precipitate; but by adding a little sulphuric acid in excess thereon, it is re-dissolved, and leaves the precipitate entirely white. This combination is only dissolved in part by dilute sulphuric acid, and the greatest quantity of that separates afterwards.

The sulphate of cerium and potash melts by a strong heat. Heated with charcoal, it gives sulphuret of potash and sulphuret of cerium. Melted with carbonate of potash, in closed vessels, it yields carbonate of cerium and sulphate of potash. This salt contains only one-third of oxyd of cerium.

It is dissolved in concentrated nitric acid, and, during the cooling, an acid salt, formed of acidulous sulphate of potash and a little sulphate of cerium, crystallizes. Thus the sulphate of cerium combined with potash is decomposed by concentrated nitric acid. This acid carries off the metal, and the sulphuric acid is directed wholly upon the potash, with which it forms a salt with excess of acid.

Nitric acid dissolves the calcined oxyd with difficulty, but that which is precipitated by pure or carbonated alkalies with ease. When the solution is saturated with oxygen, it is of a greenish yellow colour; but colourless, when less oxyded. Evaporated to the consistence of honey, it deposits lamellated crystals, which attract the humidity of the air. The solution has a saccharine taste; like all the other saturated solutions of cerium, it lets fall an oxyd of cerium, at a *maximum* of oxydation, in the open air. This precipitate is frequently formed of oxyd of iron. When dry, this salt is of a yellowish white co-

lour; but becomes colourless on being dissolved in a sufficient quantity of water. It dissolves readily in alcohol.

A concentrated solution of this salt takes a blood colour on account of a small quantity of iron, which, by drying, passes to a yellowish white, but is restored by a new solution.

A colourless and less oxyded nitrate of cerium is obtained by dissolving the yellowish salt in alcohol: the solution inflames, and yields a white salt.

It is destroyed by fire, which drives off its acid.

The calcined oxyd of cerium is slowly dissolved in muriatic acid in the cold, and more readily by heat; an effervescence is produced, owing to a disengagement of oxygenated muriatic acid gas. The taste of the solution is saccharine and astringent; the colour is a very faint greenish yellow; the dried saline mass is yellowish white, and attracts humidity. We only succeeded once in obtaining it crystallized. The crystals were white, brilliant, in four-sided prisms, with the points cut off. The salt dissolves readily in alcohol, and its concentrated solution burns with a yellow and sparkling flame. The residue of the salt is white, and gives a colourless solution. It is muriate of cerium at a *minimum* of oxydation.

Heated in closed vessels, the water of crystallization is first dissipated, afterwards the acid passes in the form of oxygenated muriatic acid gas. If the operation is stopped before the acid is entirely volatilized, an undecomposed muriate of cerium, at a *minimum* of oxydation, remains.

If the muriate of cerium contains iron, it all sublimes in a brown deliquescent mass. Nothing remains in the matrass but a white oxyd of cerium, which attracts the humidity of the air, and becomes yellow. Thus, sublimation with muriate of ammonia may be employed to purify muriate of cerium which contains a little iron.

Free phosphoric acid, saturated with an alkali, precipitates muriate of cerium. The precipitate is white, and soluble in muriatic acid, and in nitric acid, employed in sufficient quantity.

This salt is also obtained by digesting pure oxyd of cerium, moistened with phosphoric acid. It is not soluble in an excess of this acid.

The carbonate of ammonia precipitates muriate of cerium without effervescence. After the precipitation, carbonic acid is slowly disengaged in the form of bubbles. The residue retains its acid, even after desiccation.

Dry carbonate of cerium has a white colour, tending a little to bluish or greenish. It dissolves in the acids with effervescence. It does not lose its acid in an open fire. In closed vessels, without the contact of oxygen, it supports a gentle calcination, without being decomposed.

Free arsenic acid does not produce any change on muriate of cerium. The oxyd digested with this acid forms an insoluble salt. An excess of this acid dissolves it, and gives an acidulous arseniate of cerium. The saturated arseniate of cerium is deposited in the form of a powder during the evaporation. The residue does not crystallize, but by desiccation becomes a gelatinous, clear, and colourless mass.

The acidulous salts of cerium are not decomposed by molybdate of ammonia. The molybdate of cerium is precipitated from its saturated solutions, in the form of a white salt, which is not soluble in the acids.

Either the acidulous or saturated solutions of cerium are precipitated by oxalic acid. According to the degree of oxydation of the metal, the precipitate becomes red or white. This combination is also obtained by digesting the oxyd with free oxalic acid. An excess of acid does not dissolve it, but ammonia readily effects its solution, giving it a yellow colour.

A small quantity of oxyd is deposited by evaporation. The solution afterwards yields regular crystals in the form of needles. Pure alkalies do not occasion any precipitate.

Free tartareous acid has no action on muriate of cerium. The recently precipitated oxyd unites with this acid by digestion, and yields a tartrite of cerium, which dissolves readily in water. This salt is also precipitated from saturated solutions by tartrite of potash. Like the oxalate of cerium, it dissolves in pure ammonia, but does not crystallize.

Tartrite of cerium is not entirely soluble in water; the solution is precipitated by carbonate of soda.

This acid does not act on the muriate of cerium; but, by digestion, well concentrated benzoic acid dissolves the oxyd of cerium recently precipitated. On cooling, the solution first deposits crystals of the acid in excess, and afterwards benzoate of cerium in the form of a white powder, which adheres to the crystals of benzoic acid.

The resinous matter with which this acid is frequently united combines with the benzoate of cerium, and forms an insoluble brown powder.

Muriate of cerium is not precipitated by citric acid. But the oxyd digested with citric acid forms an insoluble saturated combination, which an excess of acid dissolves. The acidulous citrate of cerium is of a yellow colour, and does not crystallize. Alcohol deprives it of its water, and of part of its acid, but does not dissolve it.

The calcined oxyd of cerium is only very imperfectly dissolved in acetic acid, even with the assistance of heat; but that which is recently precipitated by the alkalies is dissolved with facility. The saturated acetate of cerium is soluble in water; it has a sweet taste, and gives granulated crystals, by evaporation, which do not change in the air, and are but slightly soluble in alcohol.

This salt swells in the fire, and is destroyed.

At first, succinic acid renders the saturated solutions of cerium turbid, but afterwards they become clear. Thus, a few drops of succinate of ammonia, poured into a saturated nitric or muriatic solution of this metal, occasion a precipitate, which soon disappears. On pouring in a greater quantity of this re-agent, the succinate of cerium is immediately deposited. This combination is white; it is not wholly insoluble in water, since the solution from which it was separated still retains a little, as is manifested by evaporation, or by alkalies. The salt obtained by digesting free succinic acid with the oxyd comports itself in the same manner. The acid dissolves it readily. Exposed to the fire, it burns with a blue flame.

Since the acetate of cerium is not precipitated by the succinate of ammonia, this is a certain means of obtaining the cerium freed from iron.

If crystallized gallic acid is put into a saturated solution of muriate of cerium, a small quantity of a white precipitate is formed. The alkalies augment it, and give it a clear chocolate colour. If a larger quantity of alkali is gradually added, the quantity of the precipitate and the intensity of its colour are increased; in proportion as this addition is made, the precipitate becomes of a reddish brown, and at length, by exposure to the light, gives a turbid, deep green solution.

The saturated solutions of cerium are precipitated white by the prussiates. The voluminous precipitate has much resemblance to silver precipitated by muriate of soda. An excess of acid readily dissolves this precipitate.

At the commencement, the saturated solutions of cerium are precipitated of a brownish colour by hydro-sulphuret of ammonia; but if more of this re-agent is added, the precipitate is of a deep green. The muriate of cerium alone takes a deep green colour, but if an alkali is added to it, an hydro-sulphurated combination of muriate of cerium at a *minimum* of oxydation is formed, which is rapidly precipitated of a bright green colour.

The hydro-sulphurated cerium, well dryed has a deep green colour, almost black. It is easily destroyed by heat; put into a crucible, moderately hot, it burns with a yellowish, phosphoric flame, only visible in the dark.

The sulphuret of ammonia gives a fading brown precipitate with the solutions of cerium. This sulphuret, added in excess, gives a precipitate of a grass green, which becomes bright green by desiccation: it burns with a blue flame, and the pure oxyd remains.

The muriate of cerium at a *minimum* is precipitated white by sulphuret of ammonia.

A piece of pure phosphorus was put into a solution of muriate of cerium contained in a closed vessel, and kept for several days on a stove. The bottom and sides of the vessel were covered with a white precipitate, and the piece of phosphorus was covered with a hard brown crust, from which the phosphorus was separated by heating it in warm water. This crust was tenacious, and shining in the dark. Heated, it took fire like phosphorus, and left a residue of a small quantity of oxyd, which, on being melted with borax, exhibited the characters described

above, except that the globule retained its clear green colour, after being cooled. It appears probable that these phenomena arose from the phosphorus containing cerium. But the phosphorus kept for a month in the same solution, slowly deposited a white powder; whence it is uncertain whether the formation of the crust, mentioned above, was owing to the cerium. The acid was always in excess in the solution, and the white powder had all the appearance of phosphate of cerium.

The pure alkalies do not dissolve cerium, even by fusion. By this means it is easily deprived of manganese. Pure ammonia digested with the oxyd does not dissolve it, but renders it yellowish.

The carbonated alkalies dissolve the oxyd of cerium in small quantity. The solution is yellow, and is precipitated by the acids. They also dissolve it by fusion in covered vessels. In the open fire, it oxydes too much to enter into solution.

The solutions of cerium are not precipitated by iron or zinc.

The electric pile of Volta only decomposes the salts, and the yellow oxyd adheres to the conductor.

METHOD OF OBTAINING CERIUM.

The mode of obtaining cerium employed by Bergelius was as follows:

Pure uncalcined cerite was dissolved in nitro-muriatic acid, and after saturating the clear solution with alkali, was precipitated by tartrite of potash; the precipitate well washed, heated, and digested in acetous acid, contained the pure cerium.

Or, otherwise, decompose a solution of cerium in nitro-muriatic acid, still hot but not saturated, by succinate of ammonia; a succinate of *iron* is gradually deposited. The precipitation is to be continued by means of succinate of ammonia, as long as a red precipitate is formed; the solution is then nearly deprived of iron. After having separated the succinate of iron, more ammonia is poured into it until a white precipitate appears. The solution is then left at rest, in order that the same portion of succinate of cerium may be deposited. The iron dissolved by the free muria-

tic acid is deposited at the same time, and the solution is freed from this metal. The cerium may afterwards be precipitated by ammonia, and then washed, dried, and heated.

The attempts of Vauquelin to reduce the oxyd of cerium produced only a small metallic globule. This globule was not acted upon by any of the simple acids, but it was dissolved, though slowly, by nitro-muriatic acid. The solution was reddish and gave traces of iron, but it also gave ardent marks of a peculiar metal; namely, it yielded a white precipitate by tartrite of potash and oxalate of ammonia. The metallic globule also was harder, whiter, much more brittle, and more scaly in its fracture, than pure cast iron.

ANALYSIS OF THE ORE OF CERIUM.

The following was the mode of examining the ore of cerium, employed by Bergelius, which led to the discovery of the metal.

To separate the yttria which was supposed to be in this ore, it was reduced to a fine powder, and covered with sulphuric acid; the acid was decomposed, and a considerable quantity of nitrous gas and carbonic acid gas were disengaged. The stony powder was repeatedly treated with this acid, until the insoluble residue appeared white.

The solution diluted with water was of a yellow colour, which became greenish by boiling, and afterwards red: completely dried it became of a yellowish white, but regained its red colour by attracting humidity. It is entirely dissolved in alcohol; and the solution, slightly digested, deposits a considerable quantity of oxyd of iron. It likewise deposits more oxyd of iron by remaining for some days undisturbed in a window. The decanted solution, being almost clear, was evaporated to siccity, and the calcined salt was in the form of a powder, and of the colour of bricks. Water could only dissolve the calcarious earth. Distilled vinegar could only take up a very small portion, and was not saturated, though assisted by the heat of ebullition. The evaporated acetic solution gave small granulated crystals, of a saccharine astringent

taste. They were not totally soluble in alcohol. The part of the acetous salt which was not dissolved in alcohol gave, by calcination, a brick-coloured powder, resembling that which had not been dissolved.

Ammonia precipitated the alcoholic solution in a white powder, which became yellowish in the air. It was a little soluble by carbonate of ammonia, and acquired the colour of bricks by calcination. The sediment being separated, the carbonate of ammonia produced a white precipitate, which was pure carbonate of lime. The acetous salt did not therefore contain yttria. The powder from which the calcarious earth had been separated dissolved in muriatic acid, with a disengagement of oxygenated muriatic acid gas, which indicated that there was a metallic oxyd.

Was it oxyd of manganese combined with oxyd of iron?

To ascertain this we endeavoured to develope the pure oxyd of manganese by means of tartrite of potash, according to Richter's method. We decomposed in this manner a solution of this substance in muriatic acid, perfectly neutralized by tartrite of potash; and after having washed the precipitate well, we submitted it to a slow calcination; but it only produced the brick-coloured powder.

Caustic alkali had no action on the insoluble part of the nitrate; which proves that it did not contain alumine.

To obtain the pure metallic matter in a sufficient quantity to make several assays, another portion of cerite was dissolved in nitric acid, and the solution evaporated to siccity. Water was poured on the residue, and it was precipitated with ammonia. The washed precipitate was dissolved in nitric acid. The solution, well neutralized with the alkali, was afterwards precipitated by tartrite of potash. A white powder was also precipitated from the same solution by carbonate of potash, but it was in small quantity. These precipitates were separately calcined, and both of them acquired the colour of bricks. The precipitate formed by the carbonate of potash was not dissolved by potash aided by digestion; it therefore did not contain alumine. The iron contained in the solution, precipitated with tartrite of potash, was separated

by hydro-sulphuret of ammonia. The remainder of the solution of cerite in nitric acid, which had been precipitated by caustic ammonia, gave carbonate of lime by carbonate of ammonia.

From these assays it results, that cerite contains nearly 23 parts of silex, 5.5 of carbonate of lime, 22 of oxyd of iron, and a quantity of this metallic matter, the weight of which, after calcination, rather exceeded 50 per cent. But this substance being then, as well as the iron, united with more oxygen than they contained in the cerite, we have, instead of a loss, an augmentation of weight, which probably arises from the oxygen. Neither is the loss which the cerite experienced in the calcination included in this account. We also found traces of manganese, but in so small a quantity, that potash, melted with the cerite and dissolved in water, did not give any colour.

Not having the practice which complete proportionate analyses require, the discoverer offers these results with diffidence, and in the hope that scientific men of more experience will employ themselves on this subject.

PALLADIUM.

PART LIX.

SECT. I.

NATURAL HISTORY OF PALLADIUM.

FOR the discovery of this metal we are indebted to Dr. Wollaston, who found it in the ore of platina, and who has given to it the name of palladium, from the planet that had been discovered nearly at the same time by Dr. Olbers.

PROPERTIES OF PALLADIUM.

The colour of palladium resembles that of platina, except that it is of a duller white. It possesses malleability, and may be drawn into wire of a considerable fineness. The specific gravity of palladium reaches from 10.972 to 11.482. Its power of conducting caloric is nearly equal to that of platina, which it rather surpasses in expansion by heat.*

For the purpose of making a comparison of the conducting power of different metals, Dr. Wollaston endeavoured to employ them in such a manner, that the same weight of each metal might expose the same extent of surface. With that view, he selected pieces of silver, of copper, of palladium, and platina, which had been lamellated so thin as to weigh each 10 grains to the square inch. Of these he cut slips $\frac{1}{10}$ of an inch in breadth, and

* It combines with oxygen, chlorine, and sulphur, but seems to have no action on hydrogen, azot, or carbon. DAVY.

four inches long; and having covered their surfaces with wax, he heated one extremity so as to be visibly red, and observing the distance to which the wax was melted, he found that upon the silver it had melted as far as $3\frac{1}{4}$ inches: upon the copper $2\frac{1}{2}$ inches: but upon the palladium and upon the platina only one inch each: a difference sufficient to establish the peculiarity of these metals, although the conducting power cannot be said to be simply in proportion to those distances.

In order to form some estimate of the comparative rate of expansion of these metals, Dr. Wollaston rivetted together two thin plates of platina and of palladium; and observing that the compound plate, when heated, became concave on the side of the platina, he ascertained that the expansion of palladium is in some degree the greater of the two. By a similar mode of comparison it was found that palladium expands considerably less than steel by heat; so that if the expansion of platina between the temperatures of freezing and boiling water be estimated at 9 parts in 10,000, while that of steel is known to be about 12, the expansion of palladium will probably not be much more or less than 10, or one part in 1000 by the same difference of temperature.

Palladium exposed to a higher degree of heat, and in contact with air, that is sufficient to melt gold, does not oxydate, nor is it fusible at such a temperature. On augmenting the heat considerably, it melts, and the specific gravity of the metal is increased to 11,871. Palladium, after having been fused, has an ash gray colour. Its hardness exceeds that of wrought iron.

By the file it acquires the brilliancy of platina. Palladium readily unites to sulphur: the sulphuret is exceedingly brittle. It combines with phosphorus by fusion. Liquid ammonia, on being suffered to stand on palladium, acquires a bluish hue, which is owing to a portion of palladium it holds in solution. Sulphuric acid acts feebly on palladium, even at a boiling heat. The solution of palladium in sulphuric acid is of a beautiful blue colour. Nitric and nitrous acids exercise a powerful action on palladium. The acid solution possesses bright red colours. During the solution of palladium in nitric and nitrous acids, no development of nitrous gas takes place. Muriatic acid, at a boiling heat, acts likewise on

palladium, and acquires a red colour. Nitro-muriatic acid, however, is the best solvent for palladium; the solution is beautifully red. All the solutions of palladium are decomposable by earths, and by alkalies. The precipitates are mostly of a vivid orange colour; they are partly soluble in an excess of the alkalies employed for obtaining them. The ammoniacal solution of the oxyd of palladium is of a fine greenish blue. Sulphate, nitrate, and muriate of potash, occasion an orange coloured precipitate in the solutions of palladium; the precipitates obtained from nitrate of palladium are generally of a deep orange. The solutions of palladium are decomposed by the contact of all the metals, except gold, platina, and silver. Fresh prepared muriate of tin occasions a dark orange coloured or brown precipitate, when mingled with neutralized solutions of salts of palladium. *Muriate of tin is therefore a very delicate test for palladium.* Green sulphate of iron precipitates palladium in a metallic state, and if the experiment be carefully conducted, the precipitate is nearly equal in weight to the palladium employed. Prussiate of potash occasions an olive-coloured precipitate, when dropped into a solution of palladium. The prussiate of palladium, separated by a neutral solution of prussiate of mercury, has the power, when heated to about 500° Fahr. of detonating with a noise similar to that occasioned by firing an equal quantity of gun-powder; the light produced during the detonation is proportionally feeble, and can only be seen in the dark. Hydro-sulphurets, and water holding in solution sulphurated hydrogen gas, occasion an intensely brown coloured precipitate, when mingled with solutions of palladium. Palladium readily alloys with other metals. It has the property, in common with platina, of destroying the colour of gold, when combined with that metal, even in a very minute proportion. Thus one part of palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed. Prussiate of mercury separates palladium from all its solutions; it is therefore the *best test* for detecting the presence of this metal.

Such are the leading characteristic properties of palladium; there are others not less remarkable which this metal possesses in common with platina, for which we

refer to Dr. Wollaston's paper on the discovery of palladium.*

METHOD OF OBTAINING PALLADIUM.

The most easy and expeditious method for obtaining palladium, as recommend by Dr. Wollaston, is the following.

Let any quantity of platina of commerce be dissolved in a sufficient quantity of nitro-muriatic acid, and free the solution as much as possible of its excess of acid (if it contains any) by evaporation, or by the addition of an alkali. This being done, mingle the solution with a prussiate of mercury, until no farther cloudiness ensues, taking care to leave the mixture to stand for some minutes. The yellowish-white precipitate which is there deposited is prussiate of palladium. To obtain that metal in a pure state, let the precipitate be heated to redness, and palladium will be obtained in a state of purity, amounting to about four or five tenths *per cent.* upon the quantity of the ore of platina employed.

Remark....It is no matter whether the solution of the ore of platina has been rendered neutral by evaporation of redundant acid, or saturated by the admixture of pot-ash, of soda, or ammonia, by lime or magnesia, by mercury, by copper or by iron, or whether the platina has or has not been precipitated from the solution by muriate of ammonia. The prussiate of mercury acts equally well in either case, for prussiate of mercury Dr. Wollaston found peculiarly adapted to precipitate palladium, exclusively of all other metals, on account of the great affinity of mercury for the prussic acid, which in this case prevents the precipitation of iron or copper. Dr. Wollaston observed that the proportion of mercury did not by any means influence the quantity of palladium, for he in vain endeavoured to obtain a larger portion of palladium than $\frac{4}{10}$ths or $\frac{5}{10}$ths grain from every hundred grains of the ore of platina, by using more of the prussiate of mercury, or by procuring any precipitate by the same means from a solution of pure platina.

* Nicholson's Journal, Jan. 1805, p. 34. and ibid. Feb. 1806, p. 117. and likewise Philosoph. Trans. 1805. p. 316.

The decomposition of muriate of palladium by prussiate of mercury, Dr. Wollaston observes, is not effected solely by the superior affinity of mercury for muriatic acid, but is assisted also by the greater affinity of prussic acid for palladium; for he found that prussiate of palladium may be formed by boiling oxyd of palladium in a solution of prussiate of mercury.

Other processes for obtaining palladium may be found in Dr. Wollaston's paper before quoted.

RHODIUM.

PART LX.

NATURAL HISTORY OF RHODIUM.

THIS is another metal lately discovered by Dr. Wollaston. It exists in the ore of platina. Dr. Wollaston has called it Rhodium, from the rose-colour which is peculiar to the dilute solutions of the salts containing this metal.

PROPERTIES OF RHODIUM.

The specific gravity of rhodium is about 11. Rhodium combines readily with all the metals except mercury. When an alloy of silver or gold with rhodium is digested in nitric or nitro-muriatic acid, the rhodium remains untouched; but when alloyed with three times its weight of bismuth, copper, or lead, each of these alloys may be dissolved completely in a mixture, by measure, of two parts of muriatic and one of nitric acid. The lead appears preferable, as it is reduced by evaporation to an insoluble muriate of lead. The muriate of rhodium then exhibits the rose-colour from which the name of the metal has been derived. It is not precipitable by prussiate of potash, nor by muriate of ammonia, nor by hydro-sulphuret of ammonia. Carbonate of potash, soda, or ammonia, do not disturb the solutions of rhodium; but the same alkalies in a pure state, or freed from carbonic acid, decompose the solutions of rhodium: the precipitate, which is of a yellow colour, is soluble in all the acids.

METHOD OF OBTAINING RHODIUM.

Into a solution of the ore of platina, which has been previously precipitated by the admixture of muriate of ammonia, and from which the ammoniacal muriate of platina has been separated, suspend a cylinder, or thin slips of zinc, or iron. All the metals which are left in the solution are thus thrown down in the form of a black powder. This being done, transfer the precipitate, *without drying it*, into a flask containing very dilute nitric acid, and assist the action by a gentle heat; by this means the copper and lead become dissolved. Then transfer the residue into dilute nitro-muriatic acid, and when the solution is effected, add to it a portion of muriate of soda, equal in weight to about $\frac{1}{10}$th of the ore of platina employed for obtaining the first solution: evaporate the whole by a gentle heat. The dry mass obtained contains the muriate of soda and platina, palladium, and rhodium. On washing this precipitate repeatedly in small quantities of alcohol, the muriate of platina and soda, as well as the palladium, become separated, and the salt of rhodium remains behind in a state of purity; from this the rhodium may be obtained, by merely dissolving it in water, and precipitating the solution by suspending in it a cylinder of zinc. The black powder which is obtained is rhodium. The rhodium thus prepared acquires a white metallic lustre with borax, but it appears infusible by any degree of heat. It may be rendered fusible by arsenic, and also by sulphur, both of which may again be separated by a continued heat. The metallic button thus obtained is not malleable.

For a fuller account of this metal the reader is referred to the Philosoph. Trans. 1804, p. 428.

IRIDIUM.

PART LXI.

NATURAL HISTORY OF IRIDIUM.

THIS metal has been lately discovered by Mr. Tennant, who found it in the black powder, which remains behind on treating the ore of platina with nitro-muriatic acid. The property which this metal possesses of exhibiting, during its solution in muriatic acid, a striking variety of colours arising from variations in its degrees of oxygenation, entitled Mr. Tennant to call it iridium.

Dr. Wollaston has since discovered that this metallic substance forms (in combination with another metal, called Osmium) a peculiar ore which is always mixed with the grains or ore of platina of commerce.

The following are the properties of the ore of iridium, as stated by Dr. Wollaston. It is totally insoluble in nitro-muriatic acid, and it appears in minute grains: these grains are about the size of those of crude platina, but are much harder; they are not at all malleable; they consist of lamina possessing a peculiar lustre. The specific gravity of the ore of iridium Dr. Wollaston found to be about 19.5, whereas the specific gravity of the ore of platina was only 17.7.

PROPERTIES OF IRIDIUM.

Iridium is of a white colour, and perfectly infusible. It does not combine with sulphur nor with arsenic. Lead easily unites with iridium, but may be separated again by cupellation, leaving the iridium upon the cupel in the form of a coarse black powder. Copper forms

with iridium a very malleable alloy, which, after cupellation with the addition of lead, left to Mr. Tennant a small portion of the iridium, but much less than in the former case. Iridium combines with silver. The alloy is perfectly malleable. Iridium cannot be separated from silver be cupellation. The compound of iridium and silver does not appear to be a perfect homogeneous mass, but a mere mechanical mixture: the iridium appeared to Mr. Tennant merely diffused through the substance of the silver, in the state of a fine powder. Gold alloyed with iridium is not freed from it by cupellation nor by quartation with silver. The compound is malleable, and does not differ much in colour from pure gold, though the portion of the alloy be very considerable. If the gold or silver is dissolved, the iridium is left in the form of a black powder. The other properties of iridium remain to be investigated. It is this metal which gives a red colour to the triple salts of platina with muriate of ammonia.

METHOD OF OBTAINING IRIDIUM.

The process employed by Mr. Tennant for obtaining iridium consisted in treating the black powder which always remains after the solution of the ore of platina in nitro-muriatic acid, alternately with potash and muriatic acid. Mr. Tennant introduced a quantity of the black powder before mentioned into a silver crucible, with a large portion of soda, and fused the mixture for some time. The alkaline mass being dissolved in water, had acquired a deep orange, or brownish yellow colour, but much of the powder remained undissolved. This powder, on being digested in muriatic acid afforded a dark blue solution, which afterwards became of a dusky olive green, and finally, by continuing the heat, of a deep red colour. Part of the powder being yet left undissolved by the muriatic acid, was again heated with alkali, and by the alternate application of the alkali and acid a complete solution was at last obtained. The alkaline fluid, containing the oxyd of a volatile metal (osmium) not yet noticed, but which shall be described presently, was put aside. The acid solution contained the metal iridium, (and also a small portion of osmium). To obtain the muriate of iridium, free from the other metal, the solution was evaporated to dryness; the dry mass was

again dissolved in water, and suffered to crystallize. It yielded distinct octahedral crystals. These crystals, on being dissolved in water, gave a deep red coloured solution, inclining to orange. With an infusion of galls, no precipitate was formed, but the colour was instantly and almost entirely taken away. Muriate of tin, carbonate of soda, and prussiate of potash, produced nearly the same effect. Ammonia precipitated the oxyd, but retained a part, and acquired a purple colour. The alkalies also precipitated the greater part of the oxyd, and if added in excess, a portion of the oxyd became again dissolved, which imparted to the solution a yellow colour. All the metals, except gold and platina, produced a dark or black precipitate, when mingled with the muriatic solution of iridium, and rendered it at the same time colourless. To obtain the iridium in a pure state, the octahedral crystals of muriate of iridium need merely be exposed to heat; both the muriatic acid as well as the oxygen are driven off, and the metal is obtained pure.

For a further account of this metal the reader is referred to Mr. Tennant's paper, in the Philosoph. Trans. for 1804; or Nicholson's Journal, No. 37, 1805, p. 24.

OSMIUM.

PART LXII.

NATURAL HISTORY OF OSMIUM.

THIS is another new metal discovered by Mr. Tennant. The name of osmium is given to it on account of the oxyd of it being exceedingly volatile, and diffusing, on being volatilized, a peculiar pungent odour. This metal likewise exists in the black powder, mixed with the ore of platina.

PROPERTIES OF OSMIUM.

Osmium in the state of a metal is not acted on by any acid, at least no effect is produced by boiling it for some time in nitro-muriatic acid. When heated in a silver cup with alkali, an union is easily effected; the compound is soluble in water, and the solution is of a yellowish colour.

The alkaline solution of osmium is decomposable by acids: the oxyd thus produced is soluble in water; it stains the skin of a dark colour, which cannot be effaced: tincture of galls added to the aqueous solution of osmium presently becomes of a purple colour, and afterwards changes to a deep violet. The solution of the oxyd of osmium becomes somewhat yellow, when mingled with liquid ammonia, and slightly so with carbonate of soda. It is not affected by magnesia, nor by carbonate of lime; but with lime a solution is formed of a bright yellow colour. The solution with lime gives with galls a deep red precipitate, which becomes blue by acids. It pro-

duces an effect on a solution of platina or gold, but precipitates lead of a yellowish brown, arsenic of a white, and muriate of tin of a brown colour. The oxyd of osmium becomes of a dark colour with alcohol, and after some time separates in the form of black films, leaving the alcohol colourless. The same effect is produced by sulphuric ether, and much more quickly. The oxyd of osmium parts with its oxygen to all the metals, except gold and platina. Silver being kept in a solution of it for some time, acquires a black colour; but does not entirely deprive it of its odour. Copper, tin, lime, and phosphorus, quickly produce a black or gray powder, and deprive the solution of all smell, and of the capability of turning an infusion of galls of a beautiful blue colour. This black powder, which consists of the osmium in a metallic state, and the oxyd of the metal employed to precipitate it, may be dissolved in nitro-muriatic acid, and then becomes blue with infusion of galls. If the pure oxyd of osmium deprived in water is agitated with mercury, it very soon loses its peculiar odour, and the metal combining with the quicksilver forms a perfect amalgam. Much of the mercury may be separated by squeezing it through leather, which retains the amalgam of a firmer consistence. The remaining quicksilver being distilled off, a powder is left of a dark gray or blue colour, which is *the osmium in a pure state.* Osmium exposed to heat with excess of air evaporates entirely, diffusing at the same time the peculiar smell; if the oxydation be carefully prevented, it does not seem in any degree volatile. Osmium subjected to a strong white heat, in a charcoal crucible, does not melt, nor does it suffer any apparent alteration whatever. Heated in a similar situation with copper, and with gold, it melts with each of these metals, and forms very malleable alloys. These compounds are easily soluble in nitro-muriatic acid, and yield by distillation the oxyd of osmium, possessing its usual properties. Pure osmium, though previously heated, is not soluble in acids, but readily soluble in alkalies by heat: Acids expel from the alkaline solutions, the oxyd of osmium; the precipitate has the peculiar odour, and the capability of giving to infusion of galls the vivid blue colour before mentioned.

METHOD OF OBTAINING OSMIUM.

Osmium may be obtained by fusing any quantity of the black powder which is mixed with the ore of platina, or which remains after dissolving the ore in nitro-muriatic acid, with at least four or six times its quantity of soda, or potash, dissolving the alkaline mass in water, and simply distilling the solution previously mingled with an acid.* The oxyd of osmium is thus taken up by the water, and passes over in the receiver. The sulphuric acid being the least volatile, is the most proper for this purpose. But as even of this acid a little is liable to pass over, a second slow distillation should be had recourse to, to obtain the oxyd of osmium in a pure state. The solution of the oxyd of osmium thus procured is colourless; it has a sweetish taste, and strong odour.

Another mode of obtaining the oxyd of osmium consists in distilling the black powder procured from the ore of platina with nitrate of potash. By this means the oxyd of osmium is obtained in a more concentrated state. See Tennant's paper, on two new metals found in the black powder after the solution of platina. Philos. Trans. 1804; and Nicholson's Journal, No. 37, 1805, p. 24.

* Mr. Tennant noticed that the oxyd of osmium even escapes in part by the mere affusion of water upon the dry alkaline mass, as is manifested by the pungent peculiar odour, from which property its name has been derived.

EARTHS.

PART LXIII.

THOUGH there seems to be an almost infinite variety of earthy substances scattered on the surface of this globe: yet when we examine them with a chemical eye, we find, not without surprise, that all the earth and stones which we tread under our feet, and which compose the largest rocks, as well as the numerous different specimens which adorn the cabinets of the curious, are composed of a very few simple or elementary earths, in number no more than six.

ENUMERATION OF EARTHS.

Silex,	Zircon,
Alumine,	Yttria,
Glucine,	Magnesia.

These are all the earths hitherto known: none of them yet have been decomposed, nor has the smallest proof been brought that they are compound; we must therefore consider them as simple bodies, which nature presents to us completely formed, though one or more of them enters into the composition of a great many bodies. They have a variety of properties which are common to all.

GENERAL PHYSICAL PROPERTIES OF EARTHS.

All earths are dry incombustible bodies. They are insoluble in water and alcohol, or nearly so. They have

little or no taste. Their specific gravity does not exceed 4.9. When perfectly pure they assume the form of a white powder, harsh to the touch. They are infusible. They are capable of combining with acids, when they form neutral salts. They are likewise disposed to unite with the alkalies, with sulphur, and phosphorus; with metallic oxyds, and with each other, either by fusion or solution in water.

Every one of these characters is not perhaps rigorously applicable to each of these bodies; but they all possess a sufficient number of them to render it useful to arrange them under one class.

Stones differ from earths principally in cohesion and hardness, and therefore are included under the same general name.

SILEX.

PART LXIV.

SECT. I.

NATURAL HISTORY OF SILEX.

SILEX, or siliceous earth, is the principal constituent part of a very great number of the compound earths and stones forming the immense mass of the solid nucleus of the globe. It is the basis of almost all the scintillating stones, such as *flint*, *rock-crystal*, *quartz*, *agate*, *calcedony*, *jasper*, &c. The sand of rivers and of the sea-shore chiefly consist of it. It is deposited in vegetable substances forming petrified wood, &c. It is likewise precipitated from certain springs in a stalactitical form. It has been discovered in several waters in a state of solution, and is found in many plants particularly grasses and equisetums. Professor Davy has proved that it forms a part of the epidermis of these vegetables. It is never met with absolutely pure in nature.

PROPERTIES OF SILEX.

Silex, when perfectly pure, exists in the form of a white powder. It is insipid and inodorous. It is rough to the touch, cuts glass, and scratches or wears away metals. Its specific gravity is about 2.66. It is unalterable by the simple combustible bodies. When mixed with water it does not form a cohesive mass. Its moleculæ when diffused in water are precipitated with the utmost facility. It is not acted on by any acid, except the fluo-

ric. When in a state of extreme division it is soluble in alkalies; fused with them it forms glass. It melts with the phosphoric and boracic acids. It is unchangeable in the air, and unalterable by oxygen and the rest of the gazeous fluids. It has been considered as insoluble in water, but it appears when in a state of extreme division to be soluble in a minute quantity.

METHOD OF OBTAINING SILEX.

Silex may be obtained tolerably pure from flints, by the following process: procure some common gun-flints, expose them in a crucible to a red heat, and then plunge them into cold water; by this treatment they will become brittle, and easily reducible to powder. Mix them, when pulverized, with three or four times their weight of carbonate of potash, and let the mixture be fused in a dull red heat, in a silver crucible. We shall thus obtain a compound of alkali and silex, called siliceous potash. Dissolve this compound in water, filter the solution, and add to it diluted sulphuric or muriatic acid. An immediate precipitation now ensues, and as long as this continues add fresh portions of acid. Let the precipitate subside; pour off the fluid that floats above it; and wash the precipitate with hot water till it comes off tasteless. This powder when dry is silex.

RATIONALE....The acid added to the solution of flint unites to the potash, and forms sulphate or muriate of potash; the siliceous earth is therefore precipitated.

REMARK....It is necessary to add excess of acid, in order that all the foreign earths which are present may be separated.

If the solution of flints be diluted with a great quantity of water, as for instance, in the proportion of 24 parts to one, and in this state an acid be poured upon it, no perceptible precipitation will ensue; the silex continues suspended in the fluid, and is invisible on account of its transparency; but it may be made to appear by evaporating part of the water.

The solution of flint, on account of its affinity with carbonic acid, is also in course of time decomposed by mere contact with air.

Another method of obtaining silex exceedingly pure is to separate it from the fluoric acid. We shall notice this process in treating of that acid.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF SILEX.

Experiment I.

Silex when mixt with water does not form a cohesive compound, but separates instantly.

LET any quantity of silex and water be mingled together in a phial, the silex will instantly separate, and the water remain transparent as before.

Experiment II.

Silex is not acted on by any acid except the fluoric.

Put a determinate quantity of silex in a Florence flask, and boil it in any quantity of sulphuric, nitric, muriatic, acetic, &c. acid; on decanting the acid and examining the earth when dry, it will be found to have sustained no loss of weight. A proof that the acid has dissolved nothing.

Experiment III.

Silex is soluble in fluoric acid.

Put one part of silex into twelve of fresh prepared fluoric acid, contained in a leaden or tin bottle; close the bottle with a stopper made of wax; let it stand for a few days, and agitate it frequently. On examining the contents, the silex will be found to be dissolved in the acid.

Experiment IV.

Silex is dissolved by alkalies in the humid way, when in a state of extreme division.

This may be proved by boiling one part of pure silex, minutely divided, in a silver vessel with twenty parts by

weight of a concentrated solution of potash or soda. The earth will be dissolved, and may be separated again by the addition of an acid.

Experiment V.

Silex is soluble in alkalies by fusion.

The method of obtaining silex, as mentioned before, furnishes a proof of this fact.

Experiment VI.

Silex is fusible with the phosphoric and boracic acids.

Place a few grains of silex and glacial acid of phosphorus, or borax, on a piece of charcoal, and urge it by means of the blow-pipe; the mixture will melt, and form a globule of transparent glass.

The other properties of this earth may be investigated without any description.

FORMATION OF GLASS.

Glass is usually obtained by mixing silex with a proper proportion of soda or potash, and exposing this mixture to a violent heat.*

When these substances are completely fused and have acquired a certain degree of heat, which is known by the fluidity of the mass, part of the melted matter is taken out at the end of a long hollow tube, which is dipped into it, and turned about until a sufficient quantity is taken up; the workman at each turn rolling it gently upon a piece of iron, to unite it more intimately. He then blows through the tube, till the melted mass at the extremity swells like a bubble; after which he rolls it again on a smooth surface to polish it, and repeats the blowing until the glass is brought as near the size and form of the vessel required, as he thinks necessary.

* Any three earths brought into fusion will also produce a glass, but not equal to the ingredients commonly employed. T. C.

If it be a common bottle, the melted matter at the end of the tube is put into a mould of the exact size and shape of its body, and the neck is formed on the outside by drawing out the ductile glass.

If it be a vessel with a large or wide orifice, the glass in its melted state is opened and widened with an iron tool; after which being again heated, it is whirled about with a circular motion, and by means of the centrifugal force thus produced is extended to the size required. Should a handle, foot, or any thing else of the kind be required, these are made separately, and stuck on in its melted state.

Window-glass is made in a similar manner, except that the mass at the end of the tube is formed into a cylindrical shape, which being cut longitudinally, by scissors or shears, is gradually bent back until it becomes a flat plate.

Large plate-glass for looking glasses, &c. is made by suffering the mass in a state of complete fusion to flow upon a casting-table, with iron ledges to confine the melted matter, and as it cools a metallic roller is passed over it to reduce it to a uniform thickness. There are different kinds of glass manufactured for different purposes; the principal of these are *flint-glass*, *crown-glass*, and *bottle-glass*.

Flint-glass is the densest, most transparent, colourless, and beautiful. It is often called *crystal*. The best kind is said to be manufactured in this capital from 120 parts of white siliceous sand, 40 parts of pearl-ash, 35 of red oxyd of lead, 13 of nitrate of potash, and 25 of black oxyd of manganese.

This is the most fusible glass. It is used for bottles and other utensils intended to be cut and polished, and for various ornamental purposes.

Crown-glass differs from the preceding in containing no lead. It is manufactured of soda and fine sand. This kind is used for panes of windows, &c.

Bottle-glass is the coarsest of all. It is made of soda and common sand. Its green colour is owing to iron. It is the least fusible.

Glass is often coloured by mixing with it, while in a fluid state, various metallic oxyds. It is coloured *blue* by the oxyd of cobalt; *red* by the oxyd of gold; *green* by

the oxyd of copper or iron; *yellow* by the oxyd of silver or antimony; and *violet* by the oxyd of manganese.

The properties of glass are well known. Its hardness is very considerable; its gravity varies from 2.3 to 4, according to the quantity of metallic oxyd which entered into its composition. Though glass when cold is brittle, it is one of the most ductile bodies known. If a thread of melted glass be drawn out and fastened to a reel, the whole of the glass can be spun off on the reel, and by cutting the threads at a certain length, there is obtained a sort of silver feather of glass. A thread of glass, when red-hot, may be drawn or spun so fine as to be scarcely visible to the naked eye. It is almost perfectly elastic, and of course is one of the most sonorous bodies. Fluoric acid dissolves it at common temperatures, and alkalies at high degrees of heat. These are the only agents known which act upon it.

Glass utensils, unless very small and thin, require to be gradually cooled in an oven. This operation is called *annealing*, and is necessary to prevent their cracking by change of temperature, wiping, or slight accidental scratches.

There are two toys made of unannealed glass, which, though commonly used for the amusement of children, exhibit phenomena which justly interest the curiosity of the philosopher, we mean Prince Rupert's drop, and the Bologna flask, or philosophical phial.

Prince Rupert's drop is made by letting drops of melted glass fall into water; the drop assumes by that means an oval form, with a tail or neck resembling a retort. These drops are said to have been invented by Prince Rupert, and are therefore called by his name. They possess the singular property, that if a small portion of the tail is broken off, the whole bursts into powder, with a kind of explosion, and a considerable shock is communicated to the hand that grasps it. Their explosion in the dark is said to be attended with a flash of light; this, however, is a mistake: a flash of light indeed is produced if the drop be broken in a glass-receiver, but in that case the flash proceeds from the action of the projected particles, forcibly striking against the body of the glass; but no such phenomenon takes place if the drop be broken in free space.

The Bologna, or philosophical phial, is a small cylindrical vessel of glass which has been suddenly cooled, open at the upper end, and rounded at the bottom. It is generally made so thick at the bottom, that it will bear a smart blow against a hard body without breaking; but if a little pebble or piece of flint is let fall into it, it immediately cracks, and the bottom falls into pieces.

REMARK....Concerning the cause of the phenomena of both these bodies, different opinions have been advanced. The most general is founded on the assumption that the dimensions of bodies which are suddenly cooled remain shorter than if the cooling had been more gradual. The dimensions, therefore, of the smooth external surface of these glasses, which are suddenly cooled, are supposed to be shorter than is adapted to the accurate envelopement of the internal part, which is necessarily cooled in a more gradual manner; if, therefore, by a crack or fissure, a solution of the continuity takes place in the external coat, the sudden action of the parts which remained in a state of tentension to recover that of perfect expansion, is supposed to effect the destruction of the mass.

Other philosophers again have been inclined to suspect that the phenomenon arises from a quantity of air being included in the substance of the glass which rushes suddenly out, if the surface which incarcerates it becomes broken. Mr. Lambert, on the contrary, maintains an opinion diametrically opposite to this: he supposes, that during the sudden cooling of the glass, vacuities are formed between its particles, and that they are sealed up by the smooth surface of the external covering, so that on the continuity of that surface being interrupted, the air suddenly rushing in occasions the bursting of the drop.

ALUMINE.

PART LXV.

SECT. I.

NATURAL HISTORY OF ALUMINE.

THIS earth derives its name from alum, of which it forms the base. It constitutes the lower strata of mountains and plains. It arrests the waters, and causes them to rise in springs to the surface of the earth. It enters into the natural composition of the schistus, and all those stones and earths called argillaceous, such as *potter's clay*, *fuller's earth*, *lepidolite*, *mica*, *corundum*, *&c.* Hitherto it has not been found in a state of absolute purity.

PROPERTIES OF ALUMINE.

Alumine is white, and soft to the touch. It is insipid, adheres to the tongue, and occasions a sense of dryness in the mouth. When moistened with a small quantity of water it forms a tenacious, ductile, kneadable paste. When heated to redness it shrinks considerably in bulk, and at last it becomes so hard as to strike fire with flint. After being ignited, it is no longer capable of being kneaded with water into a ductile mass. It recovers, however, this property by solution in an acid and subsequent precipitation. Alkalies dissolve it in the humid way, and form compounds decomposable by acids. It dissolves slowly in all acids. It possesses a powerful attraction for lime. The most intense heat of our furnaces is not able to melt it, but

it becomes fusible when lime is added. Lavoisier has proved that it is capable of entering into a kind of fusion like paste, by the action of oxygen gas; it then cuts glass and resists the file. It absorbs water and carbonic acid from the atmosphere. By its mixture with water and silex, it acquires great solidity. It does not unite with any combustible substance, but becomes fused into coloured frits with metallic oxyds. Its specific gravity is 2. It is employed in a multitude of arts.

METHOD OF OBTAINING ALUMINE.

Take any quantity of alum of commerce, dissolve it in six parts of boiling distilled water, and add to this solution, when cold, liquid ammonia, till no further precipitate ensues. Then heat the whole nearly to the boiling point for a few minutes, and transfer it on a filter. In proportion as the fluid passes off, pour more water over the precipitate till it passes tasteless. Let the precipitate obtained, while yet in a pasty state, be transferred into a glass or Wedgwood's basin, and add to it muriatic acid in small quantities at a time, until the whole is dissolved. Then evaporate the solution, till a drop of it, when suffered to cool on a plate of glass, yields minute crystals: on letting it now cool, crystals of alum will be deposited. Remove these crystals by decanting the fluid, and renew the evaporation, until, on further cooling, no more crystals are formed. Nothing now but pure alumine remains in the solution; the fluid may therefore be decomposed by adding to it gradually liquid ammonia till no further precipitate ensues. The precipitate thus obtained, when well washed and dried, is pure alumine.

Remark....The process recommended in general, by systematic writers for obtaining alumine differs from this; it consists in decomposing a solution of alum of commerce by an excess of a carbonated alkali, washing the obtained precipitate, and exposing it to a sufficient heat to drive off the carbonic acid. This method, however, is imperfect, for if the alumine thus obtained be heated with charcoal, and a diluted acid is added to the mixture, sulphurated hydrogen gas will be liberated. It adheres to the tongue;

and emits a peculiar odour when breathed upon. Sure signs that it is not pure.

It must be obvious that alumine cannot be obtained absolutely pure in this manner: for alum is a triple compound, consisting of alumine, potash, and sulphuric acid in excess. When this excess of acid is saturated, by adding to the solution an alkali, or even pure alumine, a highly insoluble salt (sulphate of alumine) is produced, differing from alum only in the proportion of its base. When we therefore gradually add to a solution of alum a carbonated alkali, the first effect of the alkali is, to saturate the excess of the sulphuric acid, and the precipitate consists principally of the salt which is insoluble in water. A further quantity of the alkali effects instantly a decomposition of part of the salt, which, in proportion as it takes place, becomes mixed with the alumine; and it is thus covered from the further action of the alkali. This being the case, it is obvious that no subsequent washing can do more than separate the sulphate of potash, and therefore the residuum, instead of being pure alumine, contains also a variable proportion of true sulphate of alumine; the sulphuric acid of which becoming decomposed on heating it in contact with charcoal, accounts for the sulphurated hydrogen gas produced by the affusion of an acid.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF ALUMINE.

Experiment I.

Alumine possesses a powerful attraction for lime.

THIS may be proved by agitating together fresh prepared lime-water and alumine. On separating the water by filtration, it will be found to be totally deprived of the lime it held in solution.

Experiment II.

Alumine is soluble in liquid alkalies.

If one part of alumine be boiled for some time, with six of potash, soda, &c. in a sufficient quantity of water, a perfect combination will take place, which may be decomposed again, either wholly or in part, by the addition of an acid.

Experiment III.

Alumine combines with silex in the humid way.

If we mingle together, a concentrated solution of alumine in potash, and a like solution of silex, and suffer the mixture to stand for a few hours, a precipitate takes place consisting of alumine and silex.

Remark....This experiment proves that there exists a strong affinity between silex and alumine. Guyton de Morveau has been deceived in every instance of the affinities, which he attributes to the earths upon each other,* excepting in this case which has been observed before him by Chenevix.† He has attributed phenomena to substances which do not partake of it, but which resulted from the impurity of its re-agents.

Experiment IV.

Alumine, sulphur and charcoal form a compound which takes fire spontaneously in atmospheric air.

(Preparation of pyrophorus.)

In order to prepare pyrophorus, equal parts of powdered alum and brown sugar are melted over the fire, and are kept stirring, till reduced to dryness. The mixture is then to be finely powdered, and introduced into a common phial, coated with clay, to which a glass tube, open at each end, is luted, to allow the escape of the gases that are produced. The phial must then be set in the fire, surrounded by sand, in a crucible. Gas will issue from the open end of the tube, and may be inflamed by a lighted paper. When this ceases to escape, the crucible may be

* Ann. de Chim. XXXI. † Phil. Trans. May, 1802.

removed from the fire; and a little moist clay pressed down upon the open end of the tube, to prevent the access of air to the contents of the phial.

The pyrophorus thus formed is a black and very light powder, which instantly takes fire, when poured out of the bottle into the air; and inflames vividly in oxygen gas.

RATIONALE.....The accension of pyrophorus is thus accounted for by Gren.* Part of the charcoal decomposes in a red heat part of the sulphuric acid of the sulphate of alumine, and becomes converted into carbonic acid gas, which escapes; the sulphuric acid is thus partly converted into sulphur, which sublimes and burns. During these changes, the potash, which is present in the alum of commerce, unites to part of the sulphur, and forms with it a sulphuret of potash, and there remains the superfluous part of the coal that had been blended with the sulphate of alumine. The constituent parts of the pyrophorus are consequently exceedingly dry potash, sulphur, charcoal, and alumine. On exposure to air, the first rapidly attracts its moisture, and is heated with it. This heat is sufficient to inflame the sulphur; because sulphur is already, by its own nature, when combined with alkaline substances, by far more disposed to decompose oxygen gas. Lastly, this ignition of the sulphur in the pyrophorus is communicated to the coaly particles, that, at the beginning of its preparation, were mingled with the sulphate of alumine.

METHOD OF MAKING POTTERY.

Pottery, or stone-ware of all sorts, from the coarsest brown pitcher to the finest porcelain, is made of alumine and silex. The use of the flint is to give strength to the ware, so that it may preserve its solidity during baking. In making the English stone-ware, care is taken to employ only the fine parts of the alumine and chert, a species of flint. With this view the alumine is much beaten in water, by which the fine parts, being mixed with the fluid, are suspended, while the coarser sink to the bottom of the vessel. The thick liquid is further purified by passing it through hair and lawn sieves of different fineness; after this the liquid is mixed into various proportions for different

* Gren's Principles of Chemistry, vol. I. p. 256.

wares, with another liquor of about the same density, and consisting of ground flints. The mixture is then gradually dried in a kiln, and after being beaten to a proper consistence it becomes fit for being formed at the wheel, into dishes, plates, bowls, &c. When the ware has been baked or exposed to a heat for a certain time, it is glazed, or made to undergo a partial vitrification at the surface, without which it would be pervious to fluids. Ordinary pottery is glazed either with oxyd of lead, or by throwing common salt over it in the furnace.

The yellow or queen's ware is made of the same substances as the common flint ware, but in different proportions. The glazing is also different; it is made by mixing together in water, to a consistence of cream, 112 parts of carbonate of lead, 24 parts of ground flint, and 6 of flint glass. The ware before it is glazed is baked in the fire, by which it acquires the property of strongly imbibing moisture; it is then dipped in this composition, and quickly taken out. It is afterwards exposed a second time to the fire, in a kiln, by which means the glaze it has imbibed is melted, a thin glossy coat is formed upon its surface, which is more or less yellow, according as a greater or less proportion of lead has been used. Porcelain, or china, is a semi-vitrified earthen ware of an intermediate nature, between common wares and glass. Chinese porcelain is said to be composed of two ingredients, one of which is a hard stone called *Petuntse*, which they carefully grind to a very fine powder; and the other, called by them *Kaolin*, is a white earthy substance, which they mix intimately with the ground stone. The former is of the siliceous, and the latter of the aluminous, nature.

The manufacture of bricks is a coarser species of the same art.

GLUCINE.

PART LXVI.

SECT. I.

NATURAL HISTORY OF GLUCINE.

FOR the discovery of this earth we are indebted to Vauquelin, who found it in 1795, in the Aigue-marine or beryl, a transparent stone of a green colour, and in the Emerald of Peru. It exists combined with silex, argil, lime, and oxyd of iron in the one; and with the same earths, with oxyd of chrome, in the other. It has lately been discovered in the Gadolinite by Mr. Ekeberg.*

Its name is taken from the Greek† word (*glukus*) which signifies sweet or saccarine, because it gives that taste to the salts it forms.

PROPERTIES OF GLUCINE.

Glucine is white, light, and soft to the touch. It is insipid, and adheres to the tongue; and is infusible by itself in the fire. Its specific gravity is 2.967. It is soluble in alkalies and their carbonates, and in all the acids except the carbonic and phosphoric, and forms with them saccharine and slightly astringent salts. It is exceedingly soluble in sulphuric acid used to excess. It is fusible with borax, and forms with it a transparent glass. It absorbs one-fourth of its weight of carbonic acid. It decomposes sulphate of alumine. It is not precipitated by the hydrosulphurets, nor by prussiate of potash, but by all the succinates. Its affinity for the acids is intermediate between magnesia and alumine.

* Journal des Mines, An. X. No. 20.

† γλυκυς.

METHOD OF OBTAINING GLUCINE.

To obtain glucine, reduce some beryl to an impalpable powder, fuse it with three times its weight of potash, and dissolve the mass in muriatic acid. Separate the silex by evaporation and filtration, and decompose the remaining fluid by adding carbonate of potash; re-dissolve the deposit when washed in sulphuric acid, and by mingling this solution with sulphate of potash, sulphate of alumine will be obtained which crystallizes.

Then mix the fluid with a solution of carbonate of ammonia, which must be used in excess; filter and boil it, and a white powder will gradually fall down, which is glucine.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF GLUCINE.

Although glucine resembles alumine in many of its properties, it possesses others which are different.

Experiment I.

DISSOLVE separately equal quantities of glucine and alumine in nitric acid to perfect saturation. The salt which results from the combination of the glucine with nitric acid does not crystallize, but forms, on drying, a kind of ductile paste; its taste is highly saccharine, and afterwards astringent. The solution of this mass, when mixed with tincture of galls, produces instantly a brown-yellow precipitate.

On the contrary, the taste of the nitrate of alumine is not sweet, and its solution does not produce any precipitate with the same re-agent.

Experiment II.

To the solution of nitrate of glucine add some oxalate of potash, no change will take place even after some days.

On adding the same re-agent to nitrate of alumine, a very copious white precipitate will be produced.

Experiment III.

Into a solution of nitrate of glucine let fall a solution of tartrite of potash, no change will be perceived.

On adding the same solution to nitrate of alumine, a flaky deposit will immediately be formed, and the supernatant fluid will be colourless.

Experiment IV.

On mixing a solution of nitrate of glucine with prussiate of potash, no change takes place.

On adding the same test to a solution of nitrate of alumine a very copious white precipitate is obtained, which becomes greenish at the end of some hours.

These experiments are sufficient to prove that glucine possesses peculiar properties, and that it is a distinct earth.

It is not yet known to what purposes glucine may be applied. If it should be discovered more abundantly hereafter, in combinations from which it can be easily separated, it may perhaps be employed for a variety of useful purposes in the arts, in chemistry, or medicine. The saccharine and slightly astringent taste of its saline combinations gives us reason to think that it possesses some salutary property, beneficial to animal economy.

ZIRCON.

PART LXVII.

SECT. I.

NATURAL HISTORY OF ZIRCON, OR JARGON.

THIS earth was discovered in the year 1793, by Klaproth of Berlin, in the Zircon or Jargon, a gem first brought from the island of Ceylon, but also found in France, Spain, and other parts of Europe.* Its colour is either gray, greenish, yellowish, reddish-brown, or purple. It has little lustre, and is nearly opaque. It is likewise found in another gem, called the hyacinth. This stone is of a yellowish red colour mixed with brown. It possesses lustre and transparency.

PROPERTIES OF ZIRCON.

Zircon earth has a white colour, is exceedingly heavy, and rough or harsh to the touch like silex. It has neither taste nor odour, and is insoluble in water, but forms with it a kind of jelly. It melts with borax into a transparent colourless glass. It suffers in a charcoal crucible a pasty fusion by intense heat, and contracts in its dimensions, acquiring a gray colour and scintillating hardness. In this state it is very hard and insoluble in acids. Its specific gravity is 4.3. Neither air nor combustible bodies act upon it. It is soluble in water, but retains while

* The French and German watches are frequently ornamented with a kind of false diamond called jargons, which probably contain this earth. Mr. Solomon W. Conrad has found the Zircon in a granitic and quartz matrix near Trenton Bridge, New-Jersey. T. C.

drying in the air a large quantity of it, which gives it the semi-transparency and appearance of a yellow jelly, or gum arabic; it exhibits the same vitreous fracture. It unites with all the acids and forms salts, differing from those of the other bases by being decomposable by alumine, glucine, the alkalies, and by mere heat. It fuses with alumine and silex. It is insoluble even by boiling in a solution of alkalies, neither can it be fused with them by means of heat; but it is soluble in alkaline carbonates.

By these properties this earth may be distinguished from every other. It is still of no use in the arts.

METHOD OF OBTAINING ZIRCON.

Reduce the mineral to powder, mix it with three times its weight of potash, and fuse it in a crucible. Wash the obtained mass in distilled water, till the whole of the potash be extracted; then dissolve the residuum as far as possible in diluted muriatic acid. Boil the solution to precipitate any silex it may contain, filter it, and gradually add solution of potash. The zircon will now become precipitated. Wash it repeatedly in distilled water, and dry it.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF ZIRCON.

Experiment I.

Sulphuric acid and zircon unite readily.

INTRODUCE zircon, gradually, into diluted sulphuric acid, until it dissolves no more when boiling hot. The salt which results from this combination is white, insoluble in water, and without any sensible taste. Heat decomposes it, and leaves the zircon pure. It is not affected by acids, but alkalies and earths decompose it. Charcoal converts it, in a high temperature, into a sulphuret, which is soluble in water, and affords by evaporation, crystals of hydro-sulphuret of zircon.

Experiment II.

Combination of nitric acid with zircon.

This combination may be effected in a similar manner to the last. It is impossible, however, to saturate the nitric acid with this earth, so as to destroy its acid properties; for the nitrate of zircon always changes the blue infusions of vegetables in the same manner as acids.

Remark....Nitrate of zircon dissolves in a small quantity of water. To obtain it in crystals, it is necessary to evaporate it in a very gentle heat, or by simple exposure to the air.

The nitrate of zircon is decomposed, 1. by sulphuric acid, which forms with it a white precipitate, soluble in an excess of that acid; 2. by carbonate of ammonia, which produces in it a deposit, soluble in an excess of that salt; 3. by an infusion of galls in alcohol, a white precipitate is produced, soluble in an excess of the infusion. The greater part of the vegetable acids take zircon from the nitric acid, and form with it insoluble compounds.

Experiment III.

The muriatic acid unites readily with zircon, when in a state of extreme comminution, or when combined with carbonic acid.

This fact may be proved, by introducing zircon into muriatic acid in the usual manner, in either state.

Remark....Muriate of zircon has no colour. Its taste is astringent. It is very soluble in alcohol, to the flame of which it does not communicate any particular colour. The muriatic acid is expelled by heat. This salt forms concretions in the mouth in consequence of being decomposed by the saliva. The solution of it affords, by a careful evaporation, small transparent needle-like crystals of a form difficult to be determined, which lose their transparency in the air, by giving out a portion of the water of crystallization.

Muriate of zircon is decomposed, 1. By sulphuric acid. A part of the sulphate of zircon which is formed

is precipitated in the form of heavy white flocks, while another portion is retained in solution by the muriatic acid. But if this acid be dissipated by heat, the remaining portion of the sulphate of zircon is gradually deposited; and if the evaporation of the liquor be stopped before that is reduced to dryness, it forms a kind of jelly, by cooling. The sulphate of zircon is therefore soluble in muriatic acid; and this solubility is increased by means of caloric.

2. The phosphoric, citric, tartareous, oxalic, and saccolactic acids decompose the muriate of zircon, and form with its base insoluble compounds, which are precipitated in the form of white flocks.

3. The gallic acid precipitates the muriate of zircon, in the *form* of a white *matter* (or in that of a grayish green, if it contains iron.) The liquor in which the gallate of zircon has been formed preserves a greenish colour; and, though fresh quantities of gallic acid do not occasion any more precipitation, the carbonate of ammonia separates a very copious flocky matter, which has a purplish colour, similar to that of lees of wine.

These experiments prove, 1. That the gallic acid has a greater affinity with zircon than the muriatic acid possesses, and that the gallate of zircon is soluble in muriatic acid, since a part of it remained in solution in the liquor which was separated by the carbonate of ammonia.

2. Carbonate of potash, saturated with carbonic acid, precipitates zircon from its solution in muriatic acid: and though this solution be made with effervescence, the precipitate, when washed and dried in the air, retains a large portion of carbonic acid, for this earth afterwards produces a lively effervescence, when dissolved in acids.

3. A solution of sulphurated hydrogen gas in water, mixed with a solution of zircon (containing iron) disturbs the transparency of the solution, and gives to it a reddish colour; but it does not occasion a true precipitate. The hydro-sulphuret of ammonia instantly precipitates this salt of a beautiful green colour which becomes black when dry. This precipitate, when placed on burning coals, gives out the smell of sulphurated hydrogen gas, and becomes of a bluish, or slightly purplish, colour by pulverization; before it has been heated it affords a

powder of a pearl gray colour. This colour is owing to the oxyd of iron combined with the zircon.

4. The carbonate of ammonia produces at first a deposition in muriate of zircon, but fresh quantities of ammoniacal salt re-dissolve the greater part of the precipitate. In this case a triple salt is formed, which may be decomposed by heat.

5. The prussiate of mercury produces in the solution of muriate of zircon a very copious precipitate, soluble in muriatic acid. The deposition cannot be owing to the combination of the mercury with the muriatic acid, for none of the salts into which it enters form a precipitate with the prussiate of mercury. Were we even to suppose this case to be an exception, still the deposition would not be soluble in simple muriatic acid.

6. A plate of zinc, introduced into a solution of muriate of zircon, occasions a slight effervescence, owing to the disengagement of hydrogen gas. The liquor becomes milky, and at the end of some days assumes the form of a white semi-transparent jelly.

7. Pure alumine, decomposes the muriate of zircon, by the assistance of a slight heat. The alumine is dissolved, the liquor becomes milky, and assumes a gelatinous form in cooling. When the muriate of zircon contains iron, it remains in solution with the alumine, so that the zircon which is precipitated does not contain any sensible quantity of that metal. See Klaproth's Beitrage. Vauquelin, Ann. de Chim. tom. xxii. p. 179.

YTTRIA.

PART LXVIII.

NATURAL HISTORY OF YTTRIA.

THE discovery of this new earth in a fossil, termed by Gadolin Ytterby, from the place where it was found, has lately been confirmed by Vauquelin and Klaproth.

PROPERTIES OF YTTRIA.

Yttria is the heaviest of the earths. Its specific gravity is 4.842. It resembles glucine in several of its properties. It is smooth and insipid. It is infusible alone, but vitrifies with sub-borate of soda. It combines with the acids, and is precipitated from those solutions by ammonia and prussiate of potash. It is also precipitated by tannin. The precipitate is not soluble in acetous acid. As some of its salts are coloured, and its weight nearly approaches to that of metals, it is considered as the link which connects the metals with the earths. It differs from glucine in not being soluble in fixed alkalies, nor being precipitated by the succinates. Its attraction for the acids is also in general stronger than that of glucine, and its saline compounds have not the same saccharine taste. Its other properties have not yet been examined.

MAGNESIA.

PART LXIX.

SECT. I.

NATURAL HISTORY OF MAGNESIA.

THIS earth is not found pure in nature, but is obtained by art from some of its combinations. It gives a peculiar character to the substances of which it forms a part. The stones which contain magnesia, in considerable quantity, have generally a smooth and unctuous feel, a greenish cast, a fibrous or striated texture, and a silky lustre. Among them we may mention, *talc*, *steatite*, *serpentine*, *chlorite*, *asbestos*, *actynolite*, *jade or nephritic stone*, *baikalite*, *boracite*, &c. It is likewise found neutralized with various acids. It has been discovered by Vauquelin, in several sea-plants.*

PROPERTIES OF MAGNESIA.

Magnesia does not form with water an adhesive ductile mass. It is in the form of a very white spongy powder, soft to the touch, and perfectly tasteless. It is very slightly soluble in water. It absorbs carbonic acid gradually from the atmosphere. It changes very delicate blue vegetable colours to green. Its attraction to the acids is weaker than those of the alkalies. Its salts are partially decomposed by ammonia, one part of the magnesia being precipitated, and the other forming a triple compound. Its specific gravity is about 2.3. It is infusible even by the most intense heat; but when mixed with some of the other earths it becomes fusible. It combines with sulphur. It does not unite to phosphorus or carbon. It is not dissolved by alkalies in the humid way. When heated

* Ann. de Chimie, XLVII. p. 78.

strongly it becomes phosphorescent. With the dense acids it becomes ignited. With all the acids it forms salts of a bitter taste, mostly very soluble.

METHOD OF OBTAINING MAGNESIA.

The usual method of procuring magnesia, is to precipitate it from sulphate of magnesia by means of an alkali.

To effect this, dissolve any quantity of sulphate of magnesia in a large quantity of distilled water, and add to it, gradually, a solution of perfectly pure sub-carbonate of potash, or soda, till no more precipitate ensues. Then collect the precipitate on a cloth, and boil it repeatedly in a large quantity of water, till this fluid passes perfectly tasteless. It is then to be dried, and exposed in a crucible to a red heat, till a sample of it, when cold, does not occasion the least effervescence with dilute acids.

RATIONALE....In this process a double decomposition takes place: the sulphuric acid of the sulphate of magnesia combines with the alkali, and forms sulphate of potash; and the carbonic acid of the alkali joins to the disengaged magnesia, and forms sub-carbonate of magnesia; the latter is precipitated, and the sulphate of potash remains in solution. On exposing the sub-carbonate of magnesia to heat, the acid is expelled, and the magnesia is left behind in a pure state.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF MAGNESIA.

EXPERIMENT I.

Magnesia converts vegetable blues into green.

MIX one part of magnesia with six of water, shake the mixture for a few minutes, and then separate the water by filtration. If this water be mingled with a pale blue mixture of tincture of cabbage, the fluid will instantly become green.

Magnesia resembles, in this respect, the alkalies, and hence it has been classed by some chemists amongst these bodies. It seems to form the link which unites the earths with the alkalies.

Experiment II.

Magnesia does not form an adhesive mass with water.

If magnesia and water be mixed together, no adhesive or ductile mass can be obtained. It is capable, however, of retaining this fluid very obstinately; for if 100 parts of magnesia are thrown into water and then dried, its weight is increased to about 18.

Experiment III.

Magnesia attracts carbonic acid from the air.

If any quantity of magnesia be exposed to the air for some time it soon attracts carbonic acid, which may be proved by pouring on it an acid, which causes a slight effervescence.

Experiment IV.

Carbonic acid has a stronger affinity for lime than for magnesia.

This may be evinced by digesting carbonate of magnesia in fresh prepared lime-water. The lime will attract the carbonic acid from the magnesia, and be rendered insoluble. Hence the taste of lime-water is totally destroyed by carbonate of magnesia.

Experiment V.

Magnesia combines with sulphur.

The other properties of this earth require no experimental investigation.

[It ought generally to be known that magnesia has been found the most efficacious among the solvents of urinary calculi, and of course one of the most efficacious remedies in athritic complaints. T. C.]

ALKALIES.

PART LXX.

WE consider these substances (one of them excepted) as simple bodies, though several chemists have asserted that they are compound; others have even endeavoured to prove this by experiment, but none of their proofs are yet satisfactory.

Were we permitted to judge from analogy we should be inclined to suppose that all alkalies possess one common base, for they have a great number of properties which are common to them all. We have, indeed, seen that one (ammonia) has been decomposed; we have proved that nitrogen enters into its composition, but no conclusion can be drawn from this. We are, therefore, forced to consider the rest of them as simple bodies, till future discoveries remove the veil which at present obstructs our view.

ENUMERATION OF ALKALIES.

Barytes,	Potash,
Soda,	Strontia,
Lime,	Ammonia.

GENERAL PHYSICAL PROPERTIES OF ALKALIES.

All alkalies are incombustible, and soluble in water; they possess an acrid urinous taste. When mixed with siliceous substances and exposed to an intense heat, they form a more or less perfect glass. They unite with another class of bodies called acids, and form new com-

pounds, in which both the acid and alkaline properties are more or less lost. They render oils miscible with water. They change various blue vegetable pigments to green; red to violet or blue; and yellow to brown. Blue pigments that have been turned red with acids are again restored by alkalies to their primitive colours. They emit light on the affusion of the dense acids when freed from water. They attract water and carbonic acid from the atmosphere. They unite to sulphur by fusion and by means of water. They exert a great solvent power on the cellular membrane and animal fibre: they also corrode woollen cloth, and if sufficiently concentrated convert it into a sort of jelly.

BARYTES.

PART LXXI.

SECT. I.

NATURAL HISTORY OF BARYTES.

BARYTES does not exist pure in nature. It is always found in combination with sulphuric or carbonic acid. United with the sulphuric acid, it forms the mineral called *sulphate of barytes*, or *baroselenite*. It is found in Staffordshire, Derbyshire, &c. When united to carbonic acid it is called *ærated barytes*, or *carbonate of barytes*, found at Anglezark, near Chorley in Lancashire. Both combinations are met with regularly crystallized and amorphous.

PROPERTIES OF BARYTES.

Pure barytes has a stronger affinity than any other body for sulphuric acid: it turns blue tincture of cabbage green. It is entirely infusible by heat alone, but melts when mixed with various earths. Its specific gravity is 4.000. It changes quickly in the air, swells, becomes soft, and falls into a white powder with the acquisition of about one-fifth of its weight. This slacking is much more active and speedy than that of lime. It combines with phosphorus, which compound decomposes water rapidly. It unites to sulphur by the dry and humid way. It has a powerful attraction for water, which it absorbs with a hissing noise, and consolidates it strongly. It is soluble in twenty times its weight of cold, and twice its weight of boiling, water. Its crystals are long four-sided prisms of a satin-like appearance. It is a deadly poison to animals.

METHOD OF OBTAINING BARYTES.

1. Take native carbonate of barytes, reduce it to a fine powder, and dissolve it in a sufficient quantity of diluted nitric acid; evaporate this solution till a pellicle appears, and then suffer it to crystallize in a shallow basin. The salt obtained is nitrate of barytes: expose this nitrate of barytes to the action of heat in a china cup, or silver crucible, and keep it in a dull red heat for at least one hour, then suffer the vessel to cool, and transfer the greenish solid contents, which are pure barytes, into a well stopped bottle. When dissolved in a small quantity of distilled water and evaporated, it may be obtained in a beautiful crystalline form.

RATIONALE....The nitric acid, added to the native carbonate of barytes, unites to the barytes, and expels the carbonic acid and forms nitrate of barytes: on exposing this nitrate to heat, it parts with its nitric acid, which becomes decomposed into its constituents, leaving the barytes behind.

2. Pure barytes may likewise be obtained from its sulphate. For this purpose, boil powdered sulphate of barytes in a solution of twice or three times its weight of carbonate of potash, in a Florence flask, for about two hours, filter the solution, and expose what remains on the filter to the action of a violent heat.

RATIONALE....In this case the sulphuric acid of the barytes unites to the potash, and the carbonic acid of the latter joins to the barytes; hence sulphate of potash and carbonate of barytes are obtained. The former is in solution, and passes through the filter; the latter is insoluble, and remains behind. From this artificial carbonate of barytes, the carbonic acid may be driven off by heat.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF BARYTES.

Barytes changes blue vegetable colours green.

LET fall into a wine glass of distilled water, rendered slightly blue by the admixture of tincture of cabbage, a

few grains of barytes. The blue colour of the fluid will instantly be converted into a lively green.

Experiment II.

Barytes changes red vegetable colours violet.

If in a similar manner to water rendered red by tincture of brazil wood, a small quantity of barytes be added, the red colour will be changed into a violet.

Experiment III.

Barytes changes yellow vegetable colours brown.

Let paper, stained yellow with an infusion of turmeric, be dipped into a solution of barytes, it will lose its yellow colour and become brown.

Experiment IV.

Barytes renders oils miscible with water.

If one part of oil of olives be put into a phial and agitated together with three of a concentrated solution of barytes, a saponaceous mass will be obtained diffusible in water.

Experiment V.

Barytes gives out heat on being united to water.

If fresh-prepared barytes be sprinkled with water it gradually swells up and bursts, it solidifies the water, and becomes considerably heated. If a little more water be gradually added, it hardens with it; and, if left for some time undisturbed, becomes so hard that it forms a kind of cement: a still larger addition of this fluid changes it into a white powder exceedingly voluminous, and soluble in water.

Experiment VI.

Barytes forms glass with silex.

Put a few grains of silex and double the quantity of barytes on a piece of charcoal, urge it well with heat by means of the blow-pipe. The mixture will melt and a globule of glass will be obtained.

Experiment VII.

Barytes has a strong attraction for carbonic acid.

Let a solution of barytes be exposed to the air, it will soon acquire a pellicle, like lime-water, which after some time sinks to the bottom of the vessel.

Or, mix a little water impregnated with carbonic acid with a solution of barytes; the mixture will immediately become turbid, and a precipitate will be obtained, which in both cases is carbonate of barytes, originating from the union of the carbonic acid and the barytes.

Experiment VIII.

Barytes tinges the flame of burning alcohol yellow.

Put a little barytes into a silver spoon, pour over it strong ardent spirit, and set fire to it with a taper; the spirit will burn with a yellow flame, which will be more perceptible by heating the mixture over a candle during its burning.

Experiment IX.

Barytes disengages sulphuric acid from all its combinations.

Dissolve a grain of sulphate of soda in a wine glass full of distilled water, and add to it a few drops of a solution of barytes, white clouds will instantly be formed, and an insoluble precipitate will be gradually deposited.

Rationale....In this case the barytes unites to the sulphuric acid of the sulphate of soda, and forms with it sulphate of barytes, which is one of the most insoluble

substances that chemistry presents, requiring for a solution about 43000 times its weight of water.

Remark...Barytes having a strong affinity for sulphuric acid, any other combination of that acid may be made use of instead of sulphate of soda.

The solution of barytes, or its combinations with nitric, muriatic, or acetic acid, are therefore very excellent tests for detecting the presence of sulphuric acid. It is consequently a very important re-agent in practical chemistry.

Experiment X.

Barytes is very soluble in water, and shoots, on cooling, into regular crystals.

Take barytes, obtained in either of the processes mentioned before, put it into a Florence flask, and pour on some distilled water; boil the solution briskly till a strong pellicle appears, then filter it boiling hot through colourless bibulous paper, freed from size, and let the solution cool in a corked phial. It will shoot into regular crystals, which, if the evaporation has been carefully conducted, have the form of four-sided prisms of a brilliant and satin-like appearance.

Remark...These crystals are barytes in a state of purity. They are so soluble as to be taken up again, when heated, merely by their own water of crystallization. When exposed to a strong heat they swell and foam, and leave a dry white powder. At 60° an ounce of water dissolves only 25 grains of them.

POTASH.

(SEE APPENDIX, NO. 33.)

PART LXXII.

SECT. I.

NATURAL HISTORY OF POTASH.

IF wood or vegetables be burnt in the open air, and the ashes repeatedly washed with water till it passes tasteless, and if this liquid be evaporated to dryness, the substance which remains is called *potash*; far, however, from being in a state of purity. In this state it occurs in commerce.

It is seldom found in an uncombined state, except in wells in towns, as at Douay, &c. It is said to exist in the aluminous ore of La Tolfa. In combination with the sulphuric, nitric, and muriatic acids, it is found in Spain, and in the East Indies.

Potash was formerly denominated the vegetable alkali, but improperly, because it is met with abundantly in mineral bodies, more especially in volcanic products. Dr. Kennedy has lately discovered it in the pumice stone. Vauquelin has found it in the Zeolite from the Ferro

islands.* Klaproth has likewise discovered it in the *Leucite*, an earth of the siliceous genus.

Vegetable physiologists are not agreed whether potash be derived from the soil in which vegetables grow; whether it exists uncombined with any acid in plants; whether it be a product of vegetation; or whether it be generated during the process of burning.

Potash was for a long time unknown in its pure state, because it was difficult to obtain it. We shall examine its properties in that state, and then point out the methods of obtaining it.

PROPERTIES OF POTASH.

Potash, in a crystallized form, consists of soft quadrangular compressed prisms, which are extremely caustic, and deliquescent. It dissolves all soft animal matters when brought into contact with it. It liquefies by a gentle heat, and rises in fumes at high temperatures. It does not unite in a direct manner with phosphorus. It easily combines with sulphur and metallic oxyds. It dissolves alumine in the humid way, and even a small quantity of silex; but it does not act on glucine or zircon, nor on magnesia or lime. It contracts no union with barytes. It absorbs water and carbonic acid rapidly. It fuses into glass with silex by the aid of fire. It forms salts which in general do not yield their acid unless to barytes. It changes blue vegetable colours green, and possesses all the general properties of alkalies.

METHODS OF OBTAINING POTASH.

It has long been a desideratum with chemists to possess a method of preparing potash in a state of absolute purity; the strong tendency which it has to combination renders this extremely difficult. The following are the methods now made use of.

* There are strong reasons to suspect the whole class of Zeolites to be alkaliferous. T. C.

1. Bouillon La Grange's apparatus* consists of several boxes of common deal. At the bottom put river-sand, which must be well washed, and over it add another stratum, but of a finer kind, and cover the whole with a cloth, besprinkled with wood-ashes. In the bottom of each box a hole is made, into which is fitted a glass tube, for the purpose of affording a passage to the liquor as it filters through the sand.

Having arranged the apparatus in this manner, take equal parts of quick-lime and potash of commerce, if the lime is very caustic; but in the contrary case, it requires twenty parts of lime to fifteen of potash: put water into an iron kettle, bring it nearly to a state of ebullition, and then add lime, which by its slacking will bring the water to that state completely. When it is slacked mix the potash, and form of the whole a thick liquid, which must be suffered to cool a little. Then pour the mixture into the boxes, and immediately throw water over it; but to prevent the water from making holes, when added, place over it a small board which will rise with the water.

Care must be taken to place earthen pans, or other vessels, to receive the liquor which runs through the tubes; and, that the ley may not absorb carbonic acid from the atmosphere, the vessels must be closed with care, in such a manner as to exclude the external air. It will be necessary also to keep water always over the mixture, which must be collected till it passes tasteless from the tubes.

The liquors obtained are nearly of the same degree of strength till towards the end of the process; when they grow weak suddenly.

To evaporate the water, use should be made of cast-iron pots, beginning with the last portions, which are a little weaker; and to prevent the necessity of keeping the strongest a long time in contact with the air when boiling, a strong ebullition is requisite. When the fluid is concentrated to a certain degree, any sulphate of potash that may be present will crystallize, and be precipitated.

To obtain dry potash pour the concentrated liquor into a small bason, and proceed with the evaporation, till a

* La Grange's Manuel of Chemistry, vol. i. p. 172.

little of it poured on an iron plate, or a marble slab, becomes solid.

Then put the concrete potash into a jar, and pour over it very strong alcohol; the potash alone dissolves in it; the sulphate and muriate of potash, with the portions of earth and even of carbonic acid, which it obstinately retains, or which it may have acquired from the air during the evaporation, remain at the bottom of the solution. Afterwards decant the pure liquor, and distil it in a retort till it becomes colourless. It must then be evaporated in a silver bason. On cooling, it crystallizes in white laminæ, which are sometimes three-tenths of an inch in length: or, instead of suffering it to crystallize, it may be evaporated to dryness.

2. Lowitz has given another method.* According to this chemist, the whole of the operation for obtaining potash of the greatest purity, and without the least colour, consists in this: A lixivium of potash, freed from carbonic acid in the usual manner, is evaporated to a thick pellicle. After the cooling, the foreign salt which has crystallized is to be separated, and the evaporation of the lixivium continued in an iron pot. During this second evaporation the pellicle of foreign salts, particularly of carbonate of potash, which continues to be formed, must be carefully taken off with an iron skimmer. When no more pellicle is formed, and the matter ceases to boil up, it is removed from the fire and suffered to cool, continually stirred with an iron spatula. It is then to be dissolved in double the quantity of cold water, and the solution filtered, and evaporated in a glass retort, till it begins to deposit regular crystals. If the mass should consolidate ever so little by cooling, a small quantity of water is to be added, and it must be heated again to render it fluid. After the formation of a sufficient quantity of regular crystals, the fluid, which is very brown, is to be decanted, and the salt, after being suffered to drain, must be re-dissolved in the same quantity of water. The decanted fluid must be kept in a well-closed bottle, and suffered to become clear by subsiding during several days. It must then be decanted for a second evaporation and crystallization. The process must be repeated as long as the crystals

* Nicholson's Journal, vol. i. p. 14.

afford, with the least possible quantiy of water, solutions perfectly limpid. These solutions are to be preserved in well-closed bottles, to defend them from the access of air.

The greatest difficulty of this process arises from the facility with which the fluid assumes a solid form. To obviate this inconvenience, a small portion of it may be concentrated to the point at which it becomes converted into a solid mass by cooling. The saturation of a lixivium considerably evaporated may be ascertained by throwing small pieces of this mass into it during its cooling. When these are no longer dissolved, it is a proof that it is at the required point.

With regard to the foreign salts which are mixed with the potash, the greatest portion separates by crystallization after the first evaporation. The rest is separated during the second concentration by the continual skimming of the pellicle. The little which may remain with the potash must precipitate for want of water of solution, in a lixivium, wherein the alkali itself is no longer dissolved but by its own water of crystallization.

REMARKS.

The property of alkalies to dissolve in highly rectified alcohol, with the exclusion of every foreign salt, would afford an excellent means of obtaining potash very pure, if their mutual action did not afford a new source of impurity. For when an alkali, absolutely pure and crystallized, is dissolved in spirit of wine, even without heat, the fluid assumes a very brown colour, which becomes still deeper after being decanted from the saline mass.

The crystallization of potash is very different, accordingly as the crystals are formed with cold or heat. In the first case, the crystals obtained are octahedra in groups, which contain 0.43 water of crystallization, and excite by their solution in water, even in the summer, a degree of cold very near the point of aqueous congelation. In the second case, very thin crystalline transparent blades of extraordinary magnitude are formed, which by an assemblage of lines, crossing each other in infinite direct-

tions, present an aggregate of cells or cavities, most commonly so perfectly closed that the vessel may be inverted without the escape of the smallest drop of the lixivium, though sometimes included to the amount of an ounce or two. For this reason it is necessary to break this fine crystallization, that the fluid may run off. The crystals present in their regular formation rectangular tetragonal blades, which, as they contain little water of crystallization, produce a considerable degree of heat when dissolved in water.

By exposing such alkaline crystals to a red heat in a silver crucible, they become fused; and, after cooling, afford a mass as white as snow, extremely caustic and deliquescent.

As the crystals and the lixivium, during the length of times required to drain the salt, may frequently become charged with a portion of carbonic acid, it is advisable, in order to avoid this inconvenience as much as possible, that the lixivium, as soon as it is brought to the requisite point of concentration, should be poured into a narrow-necked bottle, and well closed therein to crystallize. After the crystals are formed, the bottle is to be reversed without opening, and kept at a temperature rather warm until the crystals are well dried. During the winter, the liquor, after the first crystallization, continues to crystallize without being submitted to a new evaporation, provided only that it be exposed to a temperature somewhat colder than that wherein the first crystals were formed.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF POTASH.

Experiment I.

Potash rapidly absorbs water and carbonic acid from the atmosphere.

IF potash be exposed to the air in an open vessel, it soon attracts humidity and carbonic acid, augments in

weight, becomes liquid, and gradually assumes the state of liquid carbonate of potash. To preserve it in a state of purity it must therefore be kept in bottles well stopped and entirely filled with it.

Remark....When dry, or fused potash is dissolved in water, it first absorbs a certain quantity which it solidifies, caloric is evolved, and then the potash dissolves in the excess of water which is added. The absorption of water by potash is therefore really a combination in consequence of the affinity it exercises, and is very different from the simple extension of a salt in a liquid by solution; this is the reason why sensible caloric is evolved from potash and water, and the rest of the alkalies.

This effect does not take place but when the alkalies are in a dry state, or freed from the water of crystallization, for if they are in a crystallized state, when added to the water, *cold* is produced, because there is no water to be solidified. A solid then passes into a state of liquidity. This we have considered already more circumstantially, under the article Heat.

Experiment II.

Potash combines with silex in the dry way.

If potash and silex are fused together, a combination is obtained known under the name of glass. This product differs according to the quantities of silex and potash of which it is composed.

If three or four parts of potash be fused with one of silex, the result will be a soft brittle kind of glass, which is soluble in water. This solution is called liquid siliceous potash, or improperly liquid of flints.

To prepare this liquid, take one part of silex, reduced to a fine powder (or pure sand,) and three or four parts of potash; put these two substances into a crucible which must be only half filled, and place the crucible in the fire. As soon as the matter enters into fusion, it puffs up considerably, and continues to swell till the alkali has dissolved the silex. The crucible is to be kept uncovered as long as the effervescence lasts; but when it is over, cover the crucible, and augment the heat till the whole fuses quietly.

The contents are then poured out on a dry iron plate or stone; the matter as it cools becomes hard, and assumes the appearance of glass. This matter when pulverized and dissolved, by pouring water over it, forms liquid siliceous potash. It is decomposable by acids, and pure siliceous earth may be obtained from it in that way as mentioned before.

Experiment III.

Potash acts very powerfully upon animal substances.

Immerse a slip of woollen cloth, or a piece of muscular flesh, into a concentrated solution of potash; the animal substance will soon become destroyed, and form with the potash a homogeneous compound.

[Or boil a piece of linsey-woolsey in soap-boiler's ley: the wool will be converted into a soap; the linen thread will remain. T. C.]

Experiment IV.

Potash has a strong affinity for sulphur.

When equal parts of potash and sulphur are triturated together in a glass mortar, the sulphur soon acquires a green colour, the mass becomes pasty, its temperature is raised, and a sulphuret of potash is obtained.

Experiment V.

Potash and snow produce a great degree of cold.

When four parts of crystallized potash reduced to powder, and three of uncompressed snow, are hastily mingled together, the mixture becomes fluid, and an intense degree of cold is produced, which under proper circumstances is —51° Fahr.

Experiment VI.

Potash and dense acids produce a great degree of heat.

If equal weights of potash freed from its water of crystallization by fusion, and dense sulphuric acid are mingled together, a great degree of heat will be instantly produced, and a flash of light will be seen to pervade the mixture if the experiment be made in the dark.

SODA.

PART LXXIII.

SECT. I.

NATURAL HISTORY OF SODA.

THE name of soda is given to the next alkali, which greatly resembles potash. Hitherto we are not better acquainted with the nature of soda than with that of potash, being equally uncertain whether it previously existed ready formed in the vegetable, or if it be a combination of certain radicals effected during the process for obtaining it.

Soda frequently occurs in the mineral kingdom, united with sulphuric, muriatic, and boracic acids; it is also found in large quantities in Egypt, combined with carbonic acid. It appears to be deposited in large impure masses, under the surface of the earth, in various countries, from which it is extracted by running water. Thus it is found after the spontaneous evaporation of the water, mixed with sand in the bottom of lakes in Hungary; in the neighbourhood of Bilin in Bohemia; and in Switzerland. It occurs also in China, and near Tripoli in Syria, Egypt, Persia, and India. It frequently oozes out of walls, and crystallizes on their surface.

PROPERTIES OF SODA.

Soda differs particularly from potash by the following properties. In the fire it is rather more fusible. When exposed to the contact of the air it attracts water and carbonic acid; but it does not liquefy like potash, it merely acquires a pasty consistence, and at last crumbles into powder. It is not altered by light. It attracts sulphur and

sulphurated hydrogen more feebly. It adheres less strongly to the acids. It fuses and dissolves alumine more easily. All its other properties, its volatilization by a very high degree of heat, its acrid causticity, its solubility, its combinations with sulphur, &c. resemble those of potash.

METHOD OF OBTAINING SODA.

Soda like potash is procured by lixiviation from the ashes of burnt plants, but only from those which grow upon the sea shores. The variety of plants employed for this purpose is very considerable. In Spain, soda is procured from the different species of the *salsola salicornia* and *batis maritima*. The *zostera maritima* is burnt in some places on the borders of the Baltic. In this country we burn the various species of *fuci*; and in France they burn the *chenopodium maritimum*.

The soda thus procured is more or less pure according to the nature of the particular plant from which it is obtained. The greatest part however, is a true carbonate of soda.*

In order to obtain it in a state of purity, the carbonate of soda must be treated like potash of commerce with lime and ardent spirit, as described before.

REMARK....It is curious that some plants, which in their native soil yield only potash, afford also soda if they are cultivated in the neighbourhood of the sea, or on land occasionally inundated by it.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF SODA.

EXPERIMENT I.

Method of distinguishing soda from potash.

Let fall into a solution of the alkali to be investigated a few grains of oxalic acid; for this acid forms with pot-

* The methods of preparing soda for the English market, we have stated in Nicholson's Journal, for August, 1802.

ash oxalate of potash, which is very soluble, and on the contrary with soda it produces oxalate of soda, which is of a very difficult solubility.

Experiment II.

Formation of Soap.

The combination of soda or potash with oils, or fat in general, forms the compound called *soap*. The union of oil, &c. with potash, affords those called *soft soap*; the combination of soda with the same substances affords those called *hard soap*. It seems to be an established truth that potash combined with any kind of fat can only afford a soap, to which no cooling can give a hard consistency. The addition, however, of a certain quantity of soda, or even of muriate of soda, will produce the effect of consolidating it. The formation of white *soap* may be shown in the following manner:

Let one part of lime (previously slacked) and two of soda be boiled in twelve parts of water for half an hour, filter the lixivium through a linen cloth (pouring back the fluid upon the cloth till it passes clear) and evaporate it till its specific gravity be about 1.375, or, which is the same thing, till a phial which would contain one ounce of water will hold an ounce and three eighths of the fluid; this having been done, soap may be made by mere mixture of this ley with olive oil, in the proportion of one part of the former with two of the latter, in a glass or stone-ware vessel. This mixture being beat up from time to time with a wooden spatula, soon becomes consistent, and if left to stand for four or five days, it forms a white hard soap.

Remark....In large manufactories the ley for making soap is made no stronger than to float a new-laid egg, when the workmen begin to form the mixture. The oil, or tallow, is first boiled with a weak ley until the whole is formed into a saponaceous compound. It is then kept boiling with a stronger ley until it acquires a considerable consistence, and seems to be separating from the fluid below. This separation is a very material part of the operation; and to effect it completely a quantity of common salt is added, the materials are continually boiled

for three or four hours, and then the fire is withdrawn. The soap will now be found united at the top of the liquor, or what is called the *waste-ley*, which is of no further use, and is therefore drawn off. The soap is now melted for the last time with a ley, or even with water; it is then allowed to cool for a short time, and afterwards cast into wooden frames. The last melting is of considerable importance, as it gives the soap a compact appearance.

The tallow for making soap is reckoned good if 13 cwt. yield a ton of white soap.

Mottled soap is made in a similar manner as the last; the mottled appearance is given towards the end of the operation of boiling, by dispersing the ley through the soap, or by adding to it a quantity of a solution of sulphate of iron, which by its decomposition deposits its oxyd through the soap, and gives it an appearance of blue marble. In some manufactures the black oxyd of manganese is made use of for the same purpose.

Yellow soap is made with tallow and resin; and these are reckoned good, if 10 cwt. of tallow, and $3\frac{1}{2}$ cwt. of resin with the proper quantity of soda, afford a ton of soap.*

Soap of wool may be made by boiling shreds of woollen cloth of any kind with ley, till the whole has acquired a certain consistence. This kind of soap has been made and applied with success,† in several manufactures in France.

An ammoniacal soap may be produced, by pouring a concentrated solution of muriate of ammonia into a solution of common soap.

A soap of lime, barytes, and strontia, may be formed, by pouring solutions of these alkalies into that of common soap. These, together with the following terrene soaps, are insoluble, and possess no detergent properties.

Amongst the earthy soaps those of magnesia and alumine are the principal. Soap of magnesia is produced by mingling a solution of common soap with a solution of sulphate of magnesia. Soap of alumine is obtained by adding to a solution of soap a solution of alum of commerce.

* Nicholson's Journal, 4to edition, 1779, No. XXVIII. p. 108.
† Annales de Chimie, XXI. 27.

STRONTIA.

PART LXXIV.

SECT. I.

NATURAL HISTORY OF STRONTIA.

STRONTIA was for some time confounded with barytes. Indeed a great many of its properties are so similar to it that every thing which has been said of the latter will apply to strontia. It approaches to barytes as soda approaches to potash. Klaproth and Dr. Hope, in the year 1793, were the first who established its peculiar nature.

Strontia exists in a fossil state, and was first discovered at *Strontian*, in Argylshire in Scotland, from whence it takes its name. It is found united to carbonic acid, forming what is termed carbonate of strontia. This mineral is somewhat transparent, but it has in general a yellow or greenish tinge. Combined with sulphuric acid, it constitutes the mineral called sulphate of strontia. This fossil is of a reddish or flesh colour; it has been found lately by Mr. Clayfield, in the vicinity of Bristol, and has also been met with in Pennsylvania.*

PROPERTIES OF STRONTIA.

Strontia in a state of purity has a caustic taste, it changes blue vegetable colours green, and unites oil with water. It attracts carbonic acid strongly from the atmosphere, becomes slacked and swells up. It heats much and hardens strongly with water. It is not fusible by the blow-pipe, but becomes extremely phosphorescent. It tinges the flame of burning bodies carmine-red if moisture be pre-

* Cœlestine, so called from its blue colour. It is said to be found near Frank's town, Huntingdon county, but diligent search has been made without success in that neighbourhood. T. C.

sent. It is soluble in 200 parts of water at the common temperature; boiling water dissolves it readily; and the solution on cooling shoots into regular crystals: these are thin quadrangular plates, sometimes square, oftener parallelograms. It has a great attraction for acids, but adheres to them with less force than barytes, and even with less than potash and soda. It combines with combustible bodies, such as sulphur, phosphorus, &c. It is not poisonous to animals.

METHOD OF OBTAINING STRONTIA.

Strontia may be obtained from its native combinations by processes similar to those by which barytes is obtained. It may also be procured by exposing the native carbonate of strontia to heat: care, however, must be taken not to have the fire too strong, as the strontia in that case attacks the earthen crucible; the former methods are therefore preferable. In order to obtain it from sulphate of strontia, let a quantity of this mineral be reduced to powder; mix it with about one-sixth part of its weight of charcoal powder, and keep it for some hours red hot in a crucible. Then dissolve the mass in water, and pour nitric acid into the solution so long as a precipitate ensues. The solution is then to be filtered, evaporated till a strong pellicle appears, and suffered to crystallize. These crystals of nitrate of strontia may then be decomposed by exposing them to heat till all the nitric acid is driven off, which may be known by holding a piece of ignited charcoal over the fused nitrate; if the flame of the charcoal does not become enlarged, the acid is dispelled. In order to obtain it crystallized, it may be dissolved in boiling water, evaporated, and suffered to cool.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF STRONTIA.

EXPERIMENT I.

Strontia tinges the flame of burning bodies carmine-red.

THIS may be shown by dissolving either strontia, or nitrate, or muriate of strontia, in ardent spirit, and

setting fire to the solution, which will burn with a carmine-red flame.

REMARK....The experiment is best performed by moistening the strontia with ardent spirit in a silver spoon, setting fire to the mixture, and holding it while burning over the flame of a candle, in order to cause a quick and rapid combustion.

REMARK....It is curious that moisture is absolutely necessary, for if the alkali be totally deprived of water by heat it does not produce this effect.

A beautiful red fire may also be produced by mixing one part of nitrate of strontia with two or three parts of charcoal powder, and setting fire to the mixture with a red-hot coal or poker.

EXPERIMENT II.

Strontia combines with sulphur.

(Sulphuret of strontia.)

If equal parts of strontia and sulphur are mingled together and exposed to a red heat, the substances unite and, form a sulphuret of strontia of a yellowish brown colour.

When water is poured on sulphuret of strontia, and the solution is evaporated, hydro-sulphuret of strontia is obtained in a crystalline state, and a hydrogenated sulphuret of strontia remains in the solution.

EXPERIMENT III.

Strontia combines with phosphorus.

(Phosphuret of Strontia.)

If six parts of strontia be mixed with one of phosphorus in an iron or earthen tube closed at one end, and the mixture be heated gradually to a dull red heat, a combination takes place accompanied with a flash of light, as first noticed by Dr. Thompson. This phosphuret decomposes water, like the phosphuret of lime, discovered by Dr. Pearson.

Experiment IV.

Strontia combines with oxygenated muriatic acid; the decomposition of which, by sulphuric acid, is accompanied with a vivid emission of light and increase of temperature.

This curious fact was first noticed by Messrs. Davy and Clayfield.* In order to form oxygenated muriate of strontia, let a stream of oxygenated muriatic acid gas pass through a saturated heated solution of strontia in water till it is neutralized, which may be known by the solution having acquired an orange colour. On pouring into this fluid a quantity of sulphuric acid, a great increase of temperature takes place, accompanied with a vivid emission of light. But no light is developed, if the acid be poured upon dry oxygenated muriate of strontia.

* West Country Contrib. p. 111.

LIME.

PART LXXV.

SECT. I.

NATURAL HISTORY OF LIME.

THIS substance we have transferred from the class of earths, and placed it among the alkalies; for it possesses all the characteristic properties of these bodies in a striking manner, its sparing solubility in water only excepted.

Lime is found in great abundance in nature, though never pure, or in an uncombined state. It is always united to an acid, and very frequently to the carbonic acid, as in chalk, common lime-stone, marble, calcareous spar, &c. It is contained in the waters of the ocean; it is found in vegetables; and is the basis of the bones, shells, and other hard parts of animals. Its combination with sulphuric acid is known by the name of sulphate of lime (*gypsum*, or plaster of Paris.) Combined with fluoric acid it constitutes fluate of lime, or Derbyshire spar.

PROPERTIES OF LIME.

Lime is in solid masses, of a white colour, moderately hard, but easily reducible to powder. Its taste is bitter, urinous, and burning. It changes blue cabbage juice to a green. It is unalterable by the heat of our furnaces. It splits and falls into powder in the air, and loses its strong taste. It is augmented in weight and in size, by slowly absorbing water from the atmosphere. Its specific gravity is 2.3. It combines with phosphorus by heat. It unites to

sulphur both in the dry and humid way. It absorbs sulphurated hydrogen gas. It unites with some of the metallic oxyds. Its slacking by water is attended with heat, hissing, splitting, and swelling up, while the water is partly consolidated and partly converted into vapour; and the lime is reduced into a very voluminous dry powder, when it has been sprinkled with only a small quantity of water. It is soluble when well prepared in 300 parts of water. It unites to acids. It renders silex and alumine fusible, and more particularly these two earths together.

METHOD OF OBTAINING LIME.

Since the carbonic acid may be separated from the native carbonate of lime, this becomes a means of exhibiting the lime in a state of tolerable purity. For this purpose, introduce into a porcelain or earthen retort, or rather into a tube of green glass, well coated over with lute, and placed across a furnace, some powdered Carara marble, or oyster-shell powder. Adapt to its lower extremity a bent tube of glass conveyed under a bell. If we then heat the tube, we obtain carbonic acid gas; and lime will be found remaining in the tube or retort.

Remark....The burning of lime in the large way depends on the disengagement of the carbonic acid by heat: and, as lime is infusible in our furnaces, there would be no danger from too violent a heat, if the native carbonate of lime were perfectly pure; but as this is seldom the case, an extreme degree of heat produces a commencement of vitrification in the mixed stone, and enables it to preserve its solidity, and it no longer retains the qualities of lime, for it is covered with a sort of crust which prevents the absorption of the water when it is attempted to be slacked. This is called over-burnt lime.

Remark....It is probably owing to the first circumstance that the lime prepared by lord Stanhope is so far superior to that met with in general.

In order to obtain lime in a state of great purity, the following method may be had recourse to:

Take Carara marble, or oyster-shells, reduce them to powder, and dissolve the powder in pure acetous acid; precipitate the solution by carbonate of ammonia. Let the

precipitate subside, wash it repeatedly in distilled water, let it dry, and then expose it to a white heat for some hours.

RATIONALE....The acetous acid in this operation unites to the lime and forms acetite of lime, disengaging at the same time the carbonic acid, which flies off in the gazeous state: on adding to the acetite of lime carbonate of ammonia, acetite of ammonia and an artificial carbonate of lime are formed; from the latter the carbonic acid is again expelled by exposure to heat, and the lime is left behind in a state of perfect purity.

SECT. II.

EXPERIMENTAL PROOFS OF THE PROPERTIES OF LIME.

EXPERIMENT I.

Lime condenses water rapidly, with an increase of temperature.

THIS may be shown by sprinkling a little water on some fresh burnt lime. The above-mentioned phenomena will take place, and the lime will fall into powder.* The degree of heat produced, if a large piece of lime be slacked, is even sufficient to set fire to a brimstone match, if the latter be introduced into the crack of it. For similar reasons, vessels loaded with lime have been set on fire.

EXPERIMENT II.

Lime has a strong attachment for carbonic acid.

If we bring a jar filled with carbonic acid gas in contact with lime-water, and agitate the latter, a rapid diminution will ensue, and the lime-water become milky. It may also be shown by letting a current of carbonic acid gas pass into lime-water. Lime also takes this acid from alkalies. See p. 226.

RATIONALE....The carbonic acid unites with the dissolved lime, and forms carbonate of lime, which on account of its insolubility is precipitated.

* One thousand parts lime, when slacked, make 1287 parts. LAVOISIER.

When two parts lime and one part ice, each at 32° Fah. are mixed, they combine rapidly and the mixture becomes 212° Fah.

REMARK....Though lime saturated with carbonic acid forms an insoluble compound, yet when super-saturated with it the product is re-dissolved, as will be evident from the following

EXPERIMENT III.

Lime sur-saturated with carbonic acid is soluble in water.

Add to a jar about one-fourth filled with lime-water, gradually, a very small quantity of water impregnated with carbonic acid; a milkiness will ensue, because the carbonic acid forms with the lime an insoluble compound. On adding more of the water, and shaking the jar as these additions are made, the milkiness at last disappears, and the whole precipitate becomes re-dissolved. Hence it is evident that lime, with a small quantity of carbonic acid, is insoluble; and, with a larger quantity, becomes again dissolved in water.

The carbonate of lime dissolved by an excess of acid is again separated, when this excess is driven off. Thus boiling, which expels the super-abundant acid, again precipitates the carbonate.

REMARK....It is thus that nature dissolves calcareous masses, which have been collected and deposited by the waters. When the waters, by their exposure to the air, lose that quantity of carbonic acid which favoured the solution of the lime, deposits are formed, and hence the *stalactites* and incrustations found in caverns, springs, &c. and even the foliaceous calcareous *strata* of rocks, which without doubt have been held in solution.

When these waters suddenly lose the acid which was essential to the solution, there is an irregular precipitation; hence those tender calcareous cellular stones, and perhaps also the spongy *tuffs*: but if the evaporation of the carbonic acid takes place slowly, it produces crystallizations, such as *stalactites*, &c. All this, therefore, proves that carbonate of lime is not dissolved in water but by an excess of carbonic acid.

EXPERIMENT IV.

Lime absorbs carbonic acid and water from the atmosphere.

Lime-water remains unchanged in well-closed vessels; but when exposed to the open air it becomes covered with

a thin pellicle, which, on becoming thicker, breaks and falls to the bottom, making room for another new crust, till at last all the lime is separated.

RATIONALE...The cause of the alterations which the lime-water undergoes when exposed to the air originates from the carbonic acid of the atmosphere, being powerfully attracted by the lime dissolved in the water, which thus becomes converted into an insoluble carbonate of lime.

The same changes take place with lime itself when in contact with common air: it first attracts moisture and then carbonic acid; and being thereby gradually slacked, it swells up, splits, falls to pieces, and loses its sharp taste. Its weight is increased, and it becomes effervescent. It sensibly returns to the state of carbonate of lime. The greater the humidity of the air, the speedier these phenomena take place, and are the more striking. During this gradual slacking, heat is perceptible, by the absorbed water losing its caloric. It feels therefore warm, and a thermometer immersed in it rises considerably above the temperature of the surrounding medium.

EXPERIMENT V.

Lime is soluble in water, it tinges blue vegetable colours green.

When more water is added to lime than is necessary to slack it, it becomes at last dissolved. About 300 parts of water are required for one of lime. This solution is known by the name of *lime-water*. It has a pungent, alkaline taste; on adding it to an infusion of cabbage, or violets, it changes their blue colour into green.

EXPERIMENT VI.

Lime unites to sulphur both in the dry and humid way.

This has been noticed already. See sulphuret of lime.

REMARK....Sulphuret of lime has lately been proposed for bleaching, by Professor Higgins of Dublin. The alternate immersion of the cloth in the oxygenated muriatic acid, and in a diluted solution of sulphuret of lime, is said

to produce the same effect as the alternate application of the acid, and of a solution of potash or soda.

The combination of lime with phosphorus by heat, has been noticed. See phosphuret of lime.

Experiment VII.

Lime fuses with silex and alumine at high temperatures.

Though lime is perfectly infusible as well as silex, yet if they are heated together they will become fused, provided the proportion of the former be considerably greater than that of the latter. Mixed with a third of its weight of alumine, the mass may likewise be fused with facility. A mixture of two earths, fuses with difficulty.

A mixture of these three substances fuses much easier and more completely than lime with either of them singly; thus, one part of lime and one of alumine may bring into fusion two, and even two parts and a half of silex.

PREPARATION OF MORTAR & CEMENTS.

Lime forms the principal part of the mortar or cement, used for connecting stones and bricks in buildings. It is generally made of lime, sand, and water. Its hardening is a species of crystallization, owing to a slow absorption of carbonic acid and water. No certain proportion of lime, silex, and water, for forming mortar, is adhered to in this country; we are informed, however, that in the best mortar one part of lime and two of sand are generally mixed with so much water as is sufficient to give it a certain consistence. The lime, the sand, and the water, require to be very much beaten together, in order to produce an intimate mixture and combination of them in their minutest particles, without which the mortar cannot possibly answer the intended purpose.

Water-cement, or mortar which has the property of hardening under water, may be prepared according to Guyton,* by mixing together four parts of blue clay, six of black oxyd of manganese, and nine of carbonate of lime. This mixture is to be heated to a white heat, in order to decompose the carbonate of lime; it is then mixed with

* Annales de Chimie, XXXVII, p. 259.

60 parts of sand, and, formed into mortar with a sufficient quantity of water.

Dr. Bryan Higgins has found that burnt bones improve the common mortar very much; and as the mortar prepared according to his direction is certainly the best that can be proposed, we shall shortly notice the composition of it. Take 56 parts of washed *coarse sand*, whose single grains do not exceed $\frac{1}{10}$ part of an inch in diameter, and 42 of *fine sand*. Mix and wet them with lime water, add gradually 14 parts of slacked lime, beat it well together, and lastly, add a like quantity of powdered bone-ashes.

[To make mortar that will set and grow hard when exposed to water, terras, or puzzolana is used, which is an earth containing a good deal of ochre. Its purpose may be answered by sifted smithy-slack, or by filings of iron. T. C.]

AMMONIA.

PART LXXVI.

AMMONIA is very different from all the preceding alkalies by its great volatility; its irritating and pungent odour; its easy decomposition and recomposition, and consequently its well-known nature. We are not capable of producing it pure in the solid form; but it always appears either combined with water, in a liquid state (liquid ammonia) or in the state of gas. It forms the prussic acid with ignited charcoal. It dissolves phosphorus and sulphur. It neither acts nor is acted upon by any terrene substance. It has greatly assisted the progress of modern chemistry in the knowledge of animal matters. Its nature and properties have been fully investigated under the article *ammoniacal gas*.

THEORY OF THE DECOMPOSITION AND FORMATION OF WATER.

PART LXXVII.

SECT. I.

THE physical properties of water are well known; many of them have been examined already. The object of the present part is, to show that water is a compound of two simple bodies, namely, oxygen and hydrogen, and that it may be decomposed into, and re-produced from them alternately.

DECOMPOSITION OF WATER BY CHEMICAL AGENCIES.

Take a gun-barrel, the breech of which has been removed, and fill it with iron-wire, coiled up in a spiral form. To one end of the barrel adapt a small glass retort, partly filled with water; and to the other a bent glass tube, the open end of which terminates under the shelf of the pneumatic trough. Let the barrel be placed in such a manner across a furnace, that the end to which the retort is luted be a little elevated. Then light a fire in the furnace, and, when the gun-barrel has become red-hot, apply a lamp under the retort containing the water. The steam of this fluid will thus pass through the red-hot iron barrel, and become decomposed. Its oxygen unites with the iron, and its hydrogen becomes liberated in the form of gas, and may be collected in the pneumatic trough.

The same experiment may be repeated, substituting a coated glass or earthen tube for a gun-barrel, and weighing the iron wire accurately before and after the experiment. The wire will be found to have gained weight, in proportion to the quantity of oxygen which formed the water. If this weight be added to that of the hydrogen

gas it will make up exactly the weight of the water that has disappeared.

From experiments of this kind, conducted with the utmost accuracy, as well as from synthetic investigations, it appears that water is composed of 85 parts of oxygen, and 15 of hydrogen by weight very nearly. But as hydrogen gas is *at least* eleven times lighter than common air, the proportion of gases, by volume, required to form water, is about two of hydrogen to one of oxygen.

REMARK....Water may be decomposed in a similar apparatus, by distilling it over red-hot charcoal instead of iron wire; but in this case the oxygen of the water combines with part of the charcoal and forms carbonic acid gas, while its hydrogen unites to another portion of the charcoal, and produces carbonated hydrogen gas.

DECOMPOSITION OF WATER BY ELECTRICITY AND GALVANISM.

Water has also been decomposed by the agency of electricity and galvanism. If uninterrupted electrical discharges be made to pass through a quantity of water, part of it is decomposed into oxygen and hydrogen gases, and the mixture of these gases may be again inflamed by the electric spark so as to produce water.

This fact was first discovered by a society of Dutch chemists; and the principal circumstance in the experiment is, the transmission of electrical shocks, through a confined portion of water. The apparatus employed in this experiment by Messrs. Dieman and Van Troostwyk is a glass tube, about one-eighth of an inch in diameter, and 12 inches long; one of the ends of which is sealed hermetically, a gold wire being inserted at this end, and projecting about an inch and a half within the tube. About the distance of five-eighths of an inch from the extremity of this, another wire is to be fixed, which may extend to the open end of the tube. The tube is next to be filled with distilled water, and to be placed inverted in a vessel of the same. When thus disposed, electrical shocks are to be passed, between the two ends of the wire, through the water; and if these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and will ascend, till the upper part of the wire

is uncovered by the water. As soon as this is effected, the next shock that is passed sets fire to the air; and the water rises again in the tube, a very small quantity of gas remaining. Now as hydrogen and oxygen gases in a state of admixture, are the only ones that are capable of inflaming by the electric shock; and as there is nothing in the tube, besides water, that can afford them in this experiment, we may safely infer, that the evolved hydrogen and oxygen gases arise from decomposed water.

An improved apparatus, exhibiting the same experiment with less trouble to the operator, has been invented by Mr. Cuthbertson, and may be seen described and figured in Dr. Pearson's paper, in the Phil. Trans. for 1797, or in Nicholson's Journal, Vols. 1. and 2.

We are likewise indebted to Dr. Wollaston for decomposing water in a more commodious manner than the former methods, which require a powerful electrical machine, and considerable labour. It is as follows:

Let two fine gold wires be fixed in separate small glass tubes by fusion; and let the end of these tubes be ground away till the very section or extremity of each wire is laid bare: let the other end of each tube be furnished with a larger wire connected with a metallic ball, which wire communicates with the gold wire within. These two tubes are then fixed by fusion in a larger glass tube, provided with a conical drawn aperture, through which it can be filled with water, all but a small vacuity or bubble, and then sealed. The apparatus is then complete; and if a stream of electricity or galvanism be passed through it, the water is decomposed. The apparatus will be more evident from the following sketch:

The method of decomposing water by galvanism was discovered by Messrs. Nicholson and Carlisle, in the year 1801. This discovery will, in point of importance, for ever remain among the first discoveries that have been made in philosophical chemistry. Nothing more is neces-

sary for that purpose than to take a narrow glass tube 3 or 4 inches long; fit each end with a cork, penetrated by a piece of slender iron-wire, and fill the tube with water. Let the ends of the two wires be distant from each other about three-fourths of an inch; and let the one be made to communicate with the bottom of the galvanic pile, the other with the top. On making this communication, bubbles of air will form, and ascend to the top of the tube; the wire being rapidly oxydated. In this experiment, the water is decomposed; its oxygen unites with the iron, and its hydrogen appears in the state of gas.

If this experiment be made with the substitution, for iron, of some metal that is not oxydated by water, as gold for example, we obtain a mixture of hydrogen and oxygen gases, as in the experiment of Messrs. Dieman and Van Troostwyk.

SECT. II.

RE-COMPOSITION OF WATER.

IT is, however, not sufficient to decompose water into its constituent principles, oxygen and hydrogen, to produce complete conviction; we must re-compose it with the principles which resulted from its decomposition: happily, modern chemistry has enabled us to accomplish this.

It has been proved already that oxygen and hydrogen gases, when fired in proper proportions, produce a quantity of water, equal in weight to the two gases employed; it is, therefore, obvious, that by thus exploding repeatedly portions of a mixture of these gases, a considerable quantity of water will at last be produced. This being established, it would be superfluous to dwell upon it further. To form the combustion of oxygen and hydrogen gases, for the production of water, conveniently, some particular kinds of apparatus have been invented. A simple contrivance, for showing the formation of it, we have noticed already; but the cheapest, most convenient, and most simple apparatus for that purpose has been invented by Mr. Cuthbertson, of which a description and drawing has been given in Nicholson's Journal, (4th edit.) vol. i. p. 235.

ACIDS.

PART LXXVIII.

FORMATION OF ACIDS.

ACCORDING to the theory of Lavoisier all acids consist of a certain base united to oxygen, which is considered to be the cause of acidity. We are acquainted with the bases of the sulphuric, nitric, phosphoric, arsenic, &c. acids: we know that hydrogen, carbon, and oxygen, form the bases of the citric, malic, oxalic, acetic, gallic, and all the rest of the acids called *vegetable*; and that the same substances, in combination with nitrogen, constitute those called *animal* acids, such as prussic, &c. But we are totally unacquainted with the radicals of the muriatic, boracic, and fluoric acids; they must therefore be analogically considered as simple bodies in the present state of our knowledge.

We have divided the acids into three classes, viz.

1. Acids whose bases are unknown, or undecomposable acids.
2. Acids composed of two bases.
3. Acids composed of more than two bases.

The bases which become acid by the union of oxygen are capable of being united to it in various degrees. When the oxygenation is complete they are called *perfect acids*. But if they are not saturated with oxygen, they mostly appear in a state of less acidity. In the new nomenclature the termination IC is given to the complete oxygenation of these bodies, and the termination OUS when they present themselves in an imperfect state of combination with oxygen. Hence by the name of sulphuric acid, we mean sulphur completely saturated with oxygen;

and by the name sulphur*eous* acid, we understand sulphur not saturated with oxygen.

GENERAL PHYSICAL PROPERTIES OF ACIDS.

Acids are either in the solid, liquid, or gazeous state. They excite a peculiar sensation on the palate called *sour*. They change most of the blue vegetable colours red. Most of them unite to water in all proportions, and many of them have so strong an attraction for that fluid, as to be incapable of appearing in the solid form. They all combine with alkalies so strongly as to disengage them from many other substances. They mix with the earthy and metallic substances, and form combinations attended with numerous interesting phenomena; upon the due explanation of which a great part of the science of chemistry depends.

REMARK....It must be noticed, however, that every acid does not possess all the properties here enumerated; but all possess a sufficient number to distinguish them from other substances, and this is the only purpose which artificial arrangement can possibly answer.

MURIATIC ACID.

PART LXXIX.

MURIATIC acid exists in the gazeous state, and forms muriatic acid gas, which has been considered already. The basis of this acid is unknown.

PROPERTIES OF MURIATIC ACID.

Liquid muriatic acid, or water impregnated with muriatic acid gas, is a colourless, very odorous, and pungent fluid. It emits copious white fumes in contact with moist atmospheric air; these fumes are muriatic acid gas that escapes from it, and condenses again by combining with the humidity of the air. If a wide-mouthed bottle containing strong muriatic acid be opened, and the hand brought near its orifice, a sensible warmth is perceived, which arises from the combination of the acid gas with the water of the atmosphere. Liquid muriatic acid is unalterable by any known combustible body. It disengages the carbonic, phosphoric, and sulphureous acids from all their combinations, but it is constantly expelled by the action of the sulphuric acid.

METHOD OF OBTAINING MURIATIC ACID.

Muriatic acid is best obtained by decomposing muriate of soda or common salt, by means of sulphuric acid, in the following manner:

Put into a tubulated retort, lodged in a sand heat, or supported over a lamp, and connected with Pepys's distillatory vessel, or Woulf's bottles, every one containing a small quantity of distilled water, three parts of muriate

of soda, and pour on it one of strong sulphuric acid very gradually, or rather let it be suffered to drop into the retort, by means of a hydrostatic funnel fastened into its tubulure. Muriatic acid gas will be plentifully disengaged, which passes through the neck of the retort, and becomes absorbed by the water. When the water in the first bottle is fully saturated it absorbs no more, and becomes cold, being considerably heated by the absorption of the gas; but the gas continues to pass into the next bottles, and heats the water they contain. The water thus impregnated with muriatic acid gas, is called muriatic acid, and is of the specific gravity, 1.19 at 60° Fahr.

REMARK....If sulphuric acid diluted with an equal quantity, by weight, of water, be made use of in this process, the apparatus of Pepys or Woulf may be dispensed with, and a common receiver may be used with safety.

The salts formed by the combination of muriatic acid, with different bases, are called MURIATES.

PROPERTIES OF MURIATES.

These salts yield white vapours (muriatic acid gas) by the affusion of sulphuric acid, and yellowish-green vapours (oxygenated muriatic acid gas) by nitric acid; both attended with considerable effervescence. They are decomposed by solution of silver, and are volatile at high temperatures withour decomposition.

METHODS OF OBTAINING MURIATES.

Muriate of potash, soda, ammonia, barytes, strontia, lime, magnesia, &c. may be obtained by dissolving the carbonates of these substances in muriatic acid, to perfect saturation, evaporating the solution, and suffering it to crystallize. Muriate of iron may be produced by dissolving iron filings in muriatic acid to saturation, evaporating the solution and crystallizing it. Muriate of tin, zinc, arsenic, and nickel, may be obtained in a similar manner. Muriate of lead is best prepared by pouring muriatic acid into a solution of nitrate of lead, the muriate of lead precipitates instantly. Muriate of gold is obtained by dissolving gold in nitro-muriatic acid. Muri-

ate of silver is formed by pouring muriatic acid into a solution of nitrate of silver. Muriate of copper is produced, according to Chenevix, by mixing 54.5 parts of black oxyd of copper, and 50 parts of copper obtained by precipitating that metal from its solution, by a plate of iron, and putting this mixture with muriatic acid into a well-stopped phial; the solution will then contain muriate of copper. Muriate of mercury has been noticed already. Muriate of bismuth is obtained by dissolving this metal in nitro-muriatic acid. Muriate of antimony is formed in a similar manner.

BORACIC ACID.

PART LXXX.

THE composition of this acid is also unknown. It exists united to soda in the salt called borax, or sub-borate of soda. United to lime and magnesia, it forms the mineral called borate of lime.

PROPERTIES OF BORACIC ACID.

Boracic acid appears in brilliant, glittering, white, hexahedral scales, soft and unctuous to the touch. Its taste is bitterish, with a slight degree of acidity. It is soluble in alcohol, which it causes to burn, when set on fire, with a green flame, surrounded with a white one. It is of difficult solubility in cold water, but is easily dissolved in boiling water. When heated strongly it fuses into glass. If heated with water it is carried up by the aqueous vapour. It has no action on combustible bodies.

METHODS OF OBTAINING BORACIC ACID.

1. Dissolve any quantity of sub-borate of soda* in boiling water, and add to this solution sulphuric acid, by a little at a time, till the solution be rather more than saturated. Then evaporate it slowly to one-third, and set it aside to cool; white scales will be deposited, which are boracic acid. After all the acid has been crystallized out of the solution, the salt must be re-dissolved, re-crystallized, and lastly washed in distilled water, drained on filtering paper, and then dried.

* In commerce called Borax. For the method of procuring the base of the Boracic acid, called by Davy, Boron, see his Chemistry, p. 314.

2. Boracic acid may likewise be obtained by sublimation, from two parts of sur-saturated borate of soda, one of sulphuric acid, and one of water.

The union of boracic acid with different bases forms salts, called BORATES.

PROPERTIES OF BORATES.

Borates are vitrifiable by heat, but they are not altered by combustible bodies. When concentrated solutions of them are boiled with sulphuric, nitric, or muriatic acid, they are decomposed, and deposit on cooling brilliant lamellated crystals of boracic acid.

METHODS OF OBTAINING BORATES.

Borate of soda, potash, or ammonia, may be formed by neutralizing these alkalies, with a concentrated solution of boracic acid.

Borate of lime is produced by adding a strong solution of boracic acid to lime water. Borate of magnesia is obtained by dissolving magnesia in boracic acid. Borate of alumine is formed by mingling a solution of borate of soda and sulphate of alumine. Borate of silver may be formed by pouring a solution of common borax into a solution of nitrate of silver. Borate of mercury is obtained in a like manner. Borate of copper is precipitated by mixing a solution of borax with sulphate of copper.

Borate of iron, borate of lead, borate of zinc, and borate of nickel, may be formed by adding a solution of borax of commerce to solutions of these metals in nitric or muriatic acid. The new compounds precipitate.

[Borate of Soda, is used as a flux for the blow pipe, by silver smiths and by Brasiers. T. C.

FLUORIC ACID.

PART LXXXI.

THIS is another acid of which the composition is unknown. It exists in a gazeous state, and forms fluoric acid gas. United to water it constitutes liquid fluoric acid.

PROPERTIES OF FLUORIC ACID.

The distinguishing property of fluoric acid is, its power of dissolving and volatilizing silex. Its odour resembles muriatic acid. On being exposed to a moist atmospheric air, it emits white fumes. Its action upon all the inflamble substances is very feeble; it does not afford oxygen to them. It has no action upon most of the metals, but it dissolves many of their oxyds.

METHOD OF OBTAINING FLUORIC ACID.

Put one part of fluate of lime in coarse powder into a leaden or tin retort, and pour upon it two parts of sulphuric acid. Lute the retort to a receiver of the same metal, containing one part of water, and apply a gentle heat. The fluoric acid gas disengaged will be absorbed by the water and form liquid fluoric acid, which must be kept in well-closed leaden or tin bottles, or phials coated within with wax or varnish. [100 grains fluor-spar yield 174,2 grains of sulphate of lime. DAVY.]

Fluoric acid united to different bases forms saline compounds, called FLUATES.

PROPERTIES OF FLUATES.

Fluates may be decomposed by the affusion of dense sulphuric acid; but not by heat, or by combustible bodies. When strongly heated they become phosphorescent, emitting in the dark a lambent white light.

REMARK....The fluates of lime possess particularly this last property; those fluates which exhibit the most lively and variegated colours constantly shine with a light inclining to the violet, with the single exception of the Siberian variety, which has been named *chlorophane;* and which, though of a violet colour, gives a phosphorescence of a beautiful emerald green. It emits this light even under water, under oil, or *in vacuo.* When heated too strongly it ceases to shine altogether.

METHODS OF OBTAINING FLUATES.

Fluate of potash, soda, ammonia, or magnesia, may be prepared by saturating their carbonates with fluoric acid.

Fluate of barytes is precipitated by adding fluoric acid to the nitrate, or muriate of barytes. Fluate of strontia is prepared in a similar manner.

Fluate of silex is produced by suffering fluoric acid to be in contact with silex. Fluate of iron is obtained by dissolving the red oxyd of iron in fluoric acid. Fluate of mercury, fluate of tin, and fluate of silver, are precipitated by dropping fluate of potash into the nitric or muriatic solutions of these metals.

Fluoboracic, or fluoboric gas, is obtained by distilling one part of dry boracic acid, two parts fluor spar, and twelve parts oil of vitriol in a glass retort; a gas is obtained absorbable by water. Davy.

OXYGENIZED MURIATIC ACID.

PART LXXXII.

THE name of oxygenized muriatic acid is given to the compound formed by the muriatic acid with oxygen.* By this combination, however, the acid properties of the muriatic acid are not increased, as is the case with the other acids, but, on the contrary, diminished.

Oxygenized muriatic acid exists in the state of gas, and as such has been considered already. When absorbed by water it forms liquid oxygenized muriatic acid.

PROPERTIES OF OXIGENIZED MURIATIC ACID.

Oxygenized muriatic acid, in a liquid form, is of a greenish-yellow colour. It has a styptic bitter taste, and a very suffocating odour. Instead of reddening blue vegetable colours, it has the remarkable property of rendering them white. In high temperatures, when light is excluded, phosphorus remains unaltered in liquid oxygenized muriatic acid; but if light be admitted, the colour of the acid gradually disappears, and the phosphorus is converted into phosphoric acid. It thickens oils and animal fats, and renders them less disposed to combine with alkalies. Its action upon the metals presents phenomena extremely curious and important; the oxygen of the acid unites with the metal, and the produced oxyd is afterwards dissolved by the de-oxydated acid.

For the rest of its properties, see oxygenized muriatic acid gas.

* Called by Davy, Chlorine, from its greenish yellow colour. See the note on this subject in the Appendix to Vol. I.

METHOD OF OBTAINING OXYGENIZED MURIATIC ACID.

Put into a tubulated retort, supported over a lamp, one part of black oxyd of manganese reduced to a gross powder, and pour over it three parts of concentrated muriatic acid; recline the retort in such a manner that the fluid which rises up into its neck may easily run back again into the body, and apply a receiver with a little distilled water in it; the receiver must be luted to the retort by a fillet of paper. When the effervescence, which instantly takes place on the affusion of the acid, ceases, apply a gentle heat. Oxygenized muriatic acid gas will be evolved, and the receiver become filled with yellow vapours, which are absorbed by the water. When the water has acquired a yellowish-green colour, the receiver may be removed, and another one applied till no more gas is extricated. The process may be more elegantly conducted by joining the apparatus of Pepys to the distillatory vessel. The common muriatic acid which may arise is condensed in the first bottle, and the oxygenized muriatic acid gas unites to the water in the second, third, &c.

The union of oxygenized muriatic acid with different bases forms salts, known by the name of OXYGENATED MURIATES.

PROPERTIES OF OXYGENATED MURIATES.

These salts are distinguished from all the rest by yielding oxygen gas when heated, and thus becoming converted into muriates. They detonate very violently by friction and percussion with the easily inflammable bodies.

PREPARATION OF OXYGENATED MURIATES.

Preparation of oxygenated muriate of potash.

To prepare this salt, the usual materials for obtaining oxygenized muriatic acid gas are put into a retort connected with Pepys's apparatus. A solution of potash is put into the receivers, leaving the first empty, and thus

saturating the potash by passing a current of oxygenized muriatic acid gas through it. When the saturation is nearly complete the oxygenated muriate of potash separates in crystals.

When three parts of oxygenated muriate of potash and one of sulphur are triturated in a mortar, the mixture detonates violently; the same effect is produced when the mixture is struck with a hammer on an anvil. Phosphorus detonates with oxygenated muriate of potash with a prodigious force. Similar effects are produced with other inflammable substances, or with metallic bodies. Some of them may be inflamed by the affusion of sulphuric or nitric acid.

Remark....It is singular that the oxygenized muriatic acid gas does not combine directly with the alkali, but suffers a partial decomposition; one part of it becomes actually converted into muriatic acid, and consequently forms muriate of potash; the other part receives the oxygen with which the former parted, and combines with another portion of potash, forming a salt in which the acid exists, with a larger proportion of oxygen than in its usual state of oxygenated acid. This salt, therefore, is, properly speaking, not an oxygenated muriate, but *hyper-oxygenated muriate of potash.* These singular combinations seem to be owing to the stronger attraction of the alkali to muriatic than to oxygenated muriatic acid, assisted by the attraction which the latter has for a still larger portion of oxygen.

Oxygenated muriate of soda or lime may be obtained in a similar manner. The method of producing oxygenated muriate of strontia has been noticed before.

Oxygenated muriate of copper is obtained by dissolving the oxyd of copper in cold muriatic acid, or dissolving copper by heat in muriatic acid. Oxygenated muriate of iron is produced by dissolving the red oxyd of iron in muriatic acid. Oxygenated muriate of tin is produced by passing oxygenated muriatic acid gas through a solution of muriate of tin. Oxygenated muriate of lead is obtained in a similar manner.

NITRO-MURIATIC ACID.

Nitro-muriatic acid is a mixed or compound acid analogous to the former. It was formerly known by the

name of *aqua regia.* It is produced by adding muriatic acid to the nitric: one part of the former is generally added to two of the latter.

During this combination an effervescence takes place, heat is liberated, and oxygenated muriatic acid gas becomes evolved: this action may be assisted and prolonged by the application of heat. The mixture assumes a yellow colour. It has the property of dissolving gold and platina.

RATIONALE....The muriatic acid attracts part of the oxygen of the nitric acid, thus converted partly into nitrous acid, and partly into nitrous gas; whilst the simple muriatic acid becomes converted, by this addition of oxygen, into oxygenated muriatic acid, or nitro-muriatic acid.

REMARK....The same acid combination may be produced by mingling together oxygenated muriatic acid and nitrous gas.

From what has been said before, it is obvious that the salts formerly called NITRO-MURIATES cannot exist.

[HYPER OXYMURIATIC ACID.

Mr Chevenix has inferred with great probability from the formation of the hyper oxymuriate of potash, that as muriate of potash is also formed at the same time, one part of the oxymuriatic acid, combines with an additional dose of oxygen, abstracted from that portion of acid which from being oxymuriatic, becomes muriatic acid. T. C.]

SULPHURIC ACID.

PART LXXXIII.

SULPHUR is capable of combining with two different proportions of oxygen: with the smaller quantity it forms sulphureous acid; with the larger, sulphuric acid. The last of these is the subject of our first inquiry.

PROPERTIES OF SULPHURIC ACID.

Sulphuric acid is in the form of a dense liquid, slightly viscid: it runs in *striæ*, like oil, when poured from one vessel into another. Its specific gravity is in general 1.85, at least it is prepared of that strength in some of our manufactures.* In its pure state it is colourless, and void of odour. It is of considerable fixity in the fire, and requires a strong heat for ebullition. On being mingled with water, heat is instantaneously evolved. It is not altered by oxygen, nitrogen, or hydrogen gases. It combines with nitrous acid and forms a compound which dissolves silver, but scarcely any other metal. It is decomposable by a number of inflammable substances which attract its oxygen. If brought in contact with any vegetable or animal matter, it is partially decomposed, and a quantity of carbon is disengaged, which gives the acid a brown or black colour. It oxydates and dissolves a number of the metals, either affording to them part of its oxygen, or enabling the metal to decompose the water which is present. It attracts water from the atmosphere.

* Sold under the name of oil of vitriol.

METHODS OF OBTAINING SULPHURIC ACID.

The processes employed for obtaining sulphuric acid may be reduced to two, namely, to unite sulphur to oxygen, or to separate the acid from its combinations met with in nature.

The first method is made use of in this country; for which purpose peculiar buildings or apartments, with their insides lined with lead, are constructed. In these apartments sulphur is burnt, in order to absorb oxygen from the air during its combustion. But as the sulphur would not burn or become fully oxydated in a confined quantity of air, $\frac{1}{8}$ to $\frac{1}{12}$ of nitrate of potash is previously mixed with it in order to make it burn with vivacity, or to gain oxygen from the nitric acid. The sulphuric acid which is formed is absorbed by a *stratum* of water at the bottom of the chamber. The water, after being sufficiently impregnated, is exposed to heat in large glass retorts, so as to deprive the acid of the superfluous water, the sulphureous acid, and nitrous gas, with which it is mixed.

RATIONALE.....The theory of this process has been noticed already.

REMARK....The sulphuric acid obtained in this manner is not perfectly pure, but always contains small quantities of sulphate of lead and sulphate of potash; from which it may be freed by re-distillation.

Sulphuric acid united to alkalies, earths, &c. forms saline combinations called SULPHATES.

PROPERTIES OF SULPHATES.

All the sulphates are insoluble in alcohol. Their solutions are decomposed by a solution of barytes. They become converted into sulphurets by ignited charcoal at high temperatures, but they are undecomposable by mere heat.

METHODS OF OBTAINING SULPHATES.

Sulphate of potash, soda, or ammonia may be obtained by saturating these alkalies with sulphuric acid, evapo-

rating the solution, and crystallizing it. Sulphate of magnesia and sulphate of alumine may be produced in a similar manner. Sulphate of lead may be obtained by pouring sulphuric acid into a solution of acetite of lead; the sulphate of lead precipitates. Sulphate of zinc is produced by dissolving this metal in diluted sulphuric acid, and subsequent evaporation and crystallization. Sulphate of nickel, sulphate of bismuth, and sulphate of cobalt, are produced by dissolving the metals, by the assistance of heat, in sulphuric acid, and proceeding as before.

Sulphate of iron is obtained by dissolving iron filings in diluted sulphuric acid, evaporating the solution and subsequent crystallization. This salt, if exposed to the air, soon becomes covered with a yellowish crust, because it absorbs more oxygen and becomes partially converted into an oxysulphate of iron, which is of a red colour uncrystallizable, and soluble in alcohol; it may be deprived of its excess of oxygen by passing a current of sulphurated hydrogen gas through it.

SULPHUREOUS ACID.

PART LXXXIV.

THIS constitutes the imperfect degree of oxygenation of sulphur; that is to say, the sulphur is not fully saturated with oxygen. Sulphureous acid naturally exists in the gazeous state.

PROPERTIES OF SULPHUREOUS ACID.

The acid properties of sulphureous acid are not considerable. It does not redden blue vegetable colours, but, on the contrary, renders them white. It exerts little action on metallic substances, and has a feeble attraction for the alkalies and earths. It is exceedingly volatile, and assumes the state of gas, if moisture be excluded.

For a fuller account of this acid we refer our reader back to sulphureous acid gas.

METHODS OF OBTAINING SULPHUREOUS ACID.

1. To prepared sulphureous acid, take one part of mercury and four of concentrated sulphuric acid, put them into a retort, furnished with a receiver, and connected with Pepys's apparatus. The sulphureous acid gas which is disengaged is absorbed by the water in the vessel, and constitutes sulphureous acid.

2. Sulphureous acid is likewise formed during the slow combustion of sulphur. See sulphur.

The salts formed by the combination of sulphureous acid with different bases are called SULPHITES.

PROPERTIES OF SULPHITES.

All the salts of this class yield sulphur, and are converted into *sulphates* by heat. The nitric and oxygenated muriatic acids also convert them into *sulphates*.

METHODS OF OBTAINING SULPHITES.

Sulphite of potash, soda, ammonia, barytes, or lime, may be obtained by receiving a stream of sulphureous acid gas into a concentrated solution of the base employed, and then evaporating it for crystallization. Sulphite of magnesia is produced by saturating carbonate of magnesia with sulphureous acid. Sulphite of ammonia and magnesia is obtained by mingling together solutions of sulphite of magnesia, and sulphite of ammonia. Sulphite of lead may be produced by dissolving carbonate of lead in sulphureous acid. Sulphite of bismuth and sulphite of antimony are precipitated by pouring sulphureous acid into muriate of antimony, or bismuth. Sulphite of iron may be formed in a direct manner.

PHOSPHORIC ACID.

PART LXXXV.

WHEN phosphorus is united to oxygen the result is an acid, which varies according to the quantity of oxygen which joins to the phosphorus. Phosphorus saturated with oxygen forms phosphoric acid.

PROPERTIES OF PHOSPHORIC ACID.

Phosphoric acid is capable of existing in a dry and crystallized state. When solid, and placed in contact with a small quantity of water, it dissolves, and affords a ponderous transparent fluid, void of odour. When exposed to heat it is rendered viscous; it gradually becomes more consistent, and loses its transparency. Lastly, when urged by a violent heat, in a silver or platina crucible, it melts into a transparent glass, which again attracts moisture when exposed to the air, and becomes converted into liquid phosphoric acid. When melted in an earthen crucible the acid acts upon it and fuses into a glass, which is *not soluble in water*, and exhibits *no signs of acidity*. It has a strong attraction for all the alkalies, and likewise for the earths. It acts only on a small number of metallic substances.

METHODS OF OBTAINING PHOSPHORIC ACID.

1. To obtain phosphoric acid the bones of adult animals are generally made use of. For that purpose, dilute in a spacious glass jar one pound of sulphuric acid with six or eight pounds of water; then add gradually,

and with constant stirring, one pound and a half of finely pulverized bones burnt to whiteness. An effervescence will take place. When this has ceased leave the whole on a gentle sand-bath for a few hours, taking care to stir it frequently, and to supply the loss of water which happens by evaporation. After it has been suffered to remain undisturbed, strain the whole through a cloth, and wash the residual matter repeatedly in water till it passes tasteless. The fluid thus obtained contains the phosphoric acid, contaminated with lime, and may be evaporated in a Wedgwood's, or glass basin, to any wished-for consistence.

REMARK....The phosphoric acid obtained in this manner is not pure, but contains a considerable quantity of lime. To obtain it in its pure state, carbonate of ammonia must be added until no more precipitate falls down; the precipitate is carbonate of lime, which must be separated by filtration: the fluid being then evaporated to dryness leaves phosphate of ammonia. This is exposed to heat in a china cup, till all the ammonia is disengaged, which may be known by the mass frothing no longer, but flowing quietly. On cooling, it congeals into a transparent vitreous substance, called glacial acid of phosphorus, which attracts moisture, and is soluble in water.

2. Phosphoric acid may likewise be obtained by the rapid or complete oxygenation of phosphorus, by burning it in oxygen gas, as mentioned before.

3. *Scheele* has contrived a method of converting phosphorus into phosphoric acid without combustion; namely, by the action of nitric acid.

In this operation a tubulated glass retort must be half filled with pure nitric acid, and a gentle heat applied. A small piece of phosphorus being then introduced through the tubulure will be dissolved with a rapid effervescence, and a quantity of red vapour will be disengaged. The addition of phosphorus in small pieces must be continued until the last piece added remains undissolved in the boiling acid. The piece of phosphorus which produces no further change in the acid is then to be taken out, and the fire raised to drive over the remainder of the nitric acid. The phosphoric acid will then be found

in the retort, partly in a concrete, and partly in a liquid form.

RATIONALE....In this process a decomposition of the nitric acid takes place, the phosphorus at the temperature of the heated acid attacks its oxygen, and becomes converted into phosphoric acid; and the nitrogen becomes free, and flies off in the gazeous state.

The combination of phosphoric acid with different bases forms the salts called PHOSPHATES.

PROPERTIES OF PHOSPHATES.

These salts are fusible, before the blow-pipe, into a globule of glass. They are soluble in nitric acid, from which they are precipitated by lime water. Most of them do not afford phosphorus when heated with charcoal.

METHODS OF OBTAINING PHOSPHATES.

The principal of these salts are the phosphates of soda, potash, ammonia, magnesia, barytes, and strontia. They are prepared by saturating the carbonates of these bodies with phosphoric acid, and proceeding in the manner directed for the preparation of sulphates. Phosphate of mercury is precipitated by mingling a solution of phosphate of soda and nitrate of mercury. Phosphate of copper is formed in a similar manner, by letting fall a solution of phosphate of soda into a solution of nitrate of copper. Phosphate of iron is precipitated by mixing a solution of phosphate of potash with a solution of sulphate of iron. Phosphate of lead and phosphate of bismuth are produced by dropping a solution of phosphate of soda into nitrate of lead, or bismuth. Phosphate of tin or zinc is formed in a similar manner.

PHOSPHORUS ACID.

PART LXXXVI.

WHEN phosphorus is burnt slowly, and does not become completely saturated with oxygen, it forms an acid differing from the former, called phosphorus acid.

PROPERTIES OF PHOSPHORUS ACID.

Phosphorus acid is liquid, transparent, and of considerable density. It has an unpleasant taste, and emits an alliaceous and disagreeable odour when rubbed, and especially if warmed. When heated more strongly, part of it is volatillized in the form of a white vapour which is very acute, penetrating and luminous in the dark. It is much more volatile than phosphoric acid; and always contains a greater or less quantity of phosphorus.

METHODS OF OBTAINING PHOSPHORUS ACID.

(See Appendix, No. 34.)

To obtain phosphorus acid we merely expose phosphorus to the air: the phosphorus by this means undergoes a slow combustion, and is gradually changed into phosphorus acid. To effect this in a commodious manner, sticks or pieces of phosphorus may be placed on the inclined side of a glass funnel, whose neck is received in a phial containing a little distilled water, and its base covered, but not closely. A tube, or small pieces of glass

are put into the neck of the funnel, in order to prevent the phosphorus from falling through into the phial, and to give a free passage to the air of the vessel displaced by the phosphorus acid. Care must be taken that the sticks of phosphorus touch each other as little as possible.

Phosphorus acid with alkaline, terrene, or metallic bases, forms salts called PHOSPHITES.

PROPERTIES OF PHOSPHITES.

Phosphites detonate with oxygenated muriate of potash. When heated in the open air they yield a phosphorescent flame.

METHODS OF OBTAINING PHOSPHITES.

Phosphite of potash, soda, ammonia, or lime, may be prepared by dissolving the respective corbonates in phosphorus acid, and proceeding as directed before. Phosphite of barytes and strontia are produced by mingling together phosphorus acid, and barytic or strontia water. Phosphite of magnesia is obtained by mingling phosphite of potash or soda with sulphate of magnesia. Phosphite of alumine may be produced by saturating phosphorus acid with alumine.

CARBONIC ACID.

PART LXXXVII.

CARBONIC acid exists, in the gazeous state, at common temperatures, and at any pressure of the atmosphere which we know of. It is therefore a permanent, elastic, aeriform fluid, and has been considered as such under the article carbonic acid gas, to which we refer the reader for a fuller account of it.

The combination of carbonic acid with different bases constitutes CARBONATES.

PROPERTIES OF CARBONATES.

Carbonates produce a rapid effervescence when mixed with sulphuric, nitric, muriatic, &c. acids. Most of them are decomposable by heat. Some of them are insoluble in water, but become soluble by an excess of carbonic acid. Several of the alkaline carbonates change vegetable blues to green, and have an alkaline taste.

METHODS OF OBTAINING CARBONATES.

Carbonate of potash is prepared by passing a current of carbonic acid gas, for a considerable time, through a solution of sub-carbonate of potash; or, by distilling sub-carbonate of potash with carbonate of ammonia. Carbonate of soda may be prepared in a similar manner. Carbonate of magnesia is prepared by adding carbonate of potash to a solution of sulphate of magnesia as long as any precipitate ensues. Carbonate of ammonia is ob-

tained by distilling two parts of dry carbonate of lime with one of nitrate of ammonia. Carbonate of silver is precipitated by pouring carbonate of potash or soda into a solution of nitrate of silver. Carbonate of mercury is produced in a similar manner by mingling the solution of an alkaline carbonate with nitrate of mercury. Carbonate of copper is precipitated by decomposing a solution of nitrate of copper, by a carbonated alkali. Carbonate of iron is precipitated by dropping into a solution of sulphate of iron a solution of carbonate of soda or potash. Carbonate of tin, lead, nickel, or zinc, may be produced by decomposing the solutions of these metals by the same alkalies.

NITRIC ACID.

PART LXXXVIII.

PROPERTIES OF NITRIC ACID.

NITRIC acid is liquid, colourless, and transparent, possessing in a very eminent degree all the properties of acids. It tinges the skin yellow, which does not disappear till the *epidermis* wears off. It has a strong affinity for water, and has never yet been found in nature except in combination. It produces heat when added to water. When concentrated, exhales white acrid fumes on being exposed to the air, which are nitric acid in a gazeous state. When poured on oils, charcoal, &c. it sets them on fire. It causes the sulphureous and phosphorus acids to pass to the state of sulphuric and phosphoric acids, by yielding to them part of its oxygen. It is capable of oxydating all the metals except gold, platina, titanium, and tantalium. [It consists of 29.77 azot and 70.23 oxygen. When very strong it weighs about 1.5. DAVY.]

METHODS OF OBTAINING NITRIC ACID.*

Nitric acid cannot be produced in any considerable quantity, by the direct combination of its principles, without a great deal of labour; though that it may be so formed for the sake of experiment has been shown. See Nitrogen.

The following method of obtaining nitric acid is made use of by chemists.

Take two parts of dry nitrate of potash in coarse powder, put it into a tubulated glass retort, of which it occupies no more than one-third, or one-fourth, and to which a large receiver has been luted containing a little water;

* Nitric acid may be obtained by firing together by means of the electric spark, three measures of oxygen gas, and one measure and a quarter of azotic or nitrogen gas. T. C.

then pour on it, in small quantities at a time, one part of concentrated sulphuric acid. As soon as the last quantity of the acid is introduced into the retort apply a very gentle heat, and distil slowly till no more drops issue from the neck of the retort. The acid collected in the receiver is fuming, and of a reddish or yellow colour: on being brought into contact with atmospheric air, it sends forth reddish-yellow fumes, which likewise always fill the empty space of the receiver or bottle. In order to deprive it of these fumes, the acid must be re-distilled, or at least heated for some time in a glass retort, with a very gentle heat; the fuming part will rise first, and the remainder will be deprived of all its colour and fuming property.

REMARK....The property of emitting reddish-yellow fumes does not belong to the pure nitric acid; for this is one of the characteristics of another kind of acid, called nitrous acid, which we shall presently consider. The fumes which are evolved are nitrous gas, originating from a partial decomposition of a certain part of the acid during its disengagement from the nitrate of potash; hence it is soiled with nitrous gas. On exposing the acid to heat, or re-distilling it, this nitrous gas becomes disengaged, and pale nitric acid is obtained.*

The combinations of nitric acid with different bases are called NITRATES.

PROPERTIES OF NITRATES.

These salts detonate with or inflame charcoal, and other easy inflammable bodies, at a red heat. They afford oxygen and nitrogen gases at high temperatures, and yield yellowish vapours, (nitrous acid) by the affusion of sulphuric acid, especially if heat be applied.

REMARK....It is upon the property of the detonation of nitrates with inflammable substances that the composition of gun-powder is founded, which consists of 5 parts of nitrate of potash, 1 of charcoal, and 1 of sulphur.

Powder of fusion, as it is called, consists of three parts of nitrate of potash, one of sulphur, and one of fine dry

* In consequence of the comparatively slight affinity of oxygen to this acid, it is used to oxygenate or acidify substances, which may thus be converted into acids; as the oxalic, the arsenious, &c. T. C.

saw-dust. If a small quantity of this powder is put into a walnut-shell, with a thin piece of copper coin rolled up, and the money then be covered up with the powder, it may be melted by setting fire to the mixture, which will burn vividly without injuring the shell.

A mixture of one part of nitrate of potash and two of acidulous tartrite of potash, (or common flour) after being detonated, forms what is denominated *black flux*.

White flux is produced by detonating equal parts of nitrate of potash and acidulous tartrite of potash, or flour, in a similar manner.

METHODS OF OBTAINING NITRATES.

Nitrate of potash, soda, ammonia, barytes, or strontia, may be prepared by neutralizing the carbonates of these alkalies with nitric acid, evaporating the solution and suffering it to crystallize. Nitrate of magnesia is produced in a similar manner. Nitrate of silver is obtained by dissolving silver in nitric acid, evaporating the solution until a pellicle appears, and then setting it aside to crystallize. Nitrate of mercury, copper, nickel, lime, or cobalt, may be produced in a similar manner. Nitrate of iron is obtained by dissolving iron in nitric acid. On evaporating the solution a red precipitate appears, consisting of iron oxydated to its *maximum*.

NITROUS ACID.

PART LXXXIX.

IT was until very lately a generally received notion, that the proportion of oxygen in nitrous acid was less than that existing in the nitric acid, and that it was therefore less oxygenated; but this is certainly not the case. Mr. Thompson's* remarks concerning nitrous acid, and Davy's† observations, are sufficient to prove the contrary; with these gentlemen, we consider nitrous acid as nothing more than nitric acid holding in solution, that is, loosely combined with it, a greater or less quantity of nitrous gas, and being therefore more or less coloured and fuming, according to the quantity of gas it contains.

PROPERTIES OF NITROUS ACID.

Nitrous acid exists in the state of gas, in the form of a red vapour, slightly coercible. When combined with water it is of a yellow or orange colour. It emits copious orange-coloured or red fumes. It is more decomposable than nitric acid, and inflames combustible bodies more readily. It has a strong attraction for water, and their combination is attended with an increase of temperature. Different portions of water convert its colour to a deep blue, green, yellow, &c. while the vapours still continue of their original yellowish-red colour.

METHODS OF OBTAINING NITROUS ACID.

The common mode of obtaining nitrous acid is to decompose nitrate of potash by means of sulphuric acid

* Davy's Researches, &c. p. 31. † Ibid. p. 32.

with the assistance of heat. The nitric acid, as has been stated already, suffers a partial decomposition during the process, and hence it is the nitrous acid which is obtained in the first process of distillation.

It seems to be true that nitrous acid of a much darker orange red colour is obtained by decomposing nitrate of potash by means of sulphate of iron than when the same salt is decomposed by sulphuric acid. The following is the process made use of by our manufacturers.

Take a quantity of sulphate of iron deprived of its water of crystallization by heat, and mix it with an equal weight of dry nitrate of potash; put the mixture into a glass retort, to which a very spacious receiver has been luted, containing a little water, and begin the distillation with a very slow fire. As soon as the red vapours cease to come over let the fire be slackened, and when the vessels are cooled the receiver may be cautiously withdrawn, and its contents quickly transferred through a glass funnel into a bottle, furnished with a ground stopper.

REMARK....The salts which, according to the principles of the new nomenclature, are called *nitrites*, cannot be formed by a direct combination. For the *nitric* acid only enters into combination with the body to which it is presented, and the *nitrous* gas becomes disengaged. They may, however, be obtained by partially decomposing nitrate of potash, or other nitrates, by a moderate heat. These salts, however, are more properly to be considered as compounds of the nitric acid and the substances with which it is united, to which a portion of nitrous gas slightly adheres; and this gas can be expelled by the addition of any weak acid. They have been very little examined.

ARSENIC ACID.

PART XC.

ARSENIC acid is always a product of art. It is arsenic fully oxygenated.

PROPERTIES OF ARSENIC ACID.

Arsenic acid is capable of existing in the solid state, but it is not crystallizable. It appears in the form of a white pulverulent matter. It attracts humidity from the air. It has an acid caustic taste. It is soluble in six parts of its weight of water. This solution possesses a considerable acid taste. It is not volatile, but may be evaporated to dryness and even converted into glass. It is decomposable by all combustible bodies and by many oxyds. It is soluble in some acids, but without change or intimate combination. Its specific gravity is 3.391. It consists of 91 parts of arsenic and 9 of oxygen.

METHOD OF OBTAINING ARSENIC ACID.

Take two ounces of arsenious acid in powder,* put it into a tubulated retort, pour on it six or seven ounces of muriatic acid, and apply the heat of a lamp until the arsenious acid is dissolved. Then add three or four ounces of nitric acid, and heat it again gradually. An intestine motion now takes place, and much red vapour or nitrous gas is extricated. As soon as, in the progress of the operation, the red vapours have ceased, an ounce of finely powdered arsenious acid is to be again added, and the solution effected as before, by a gentle ebullition;

* Common white arsenic.

to this two ounces of nitric acid must be added, which will produce a second effervescence and discharge of red vapours; the distillation must now be continued to dryness, and the fire must be urged towards the end, to such a degree, as to make the residual mass thoroughly red-hot. This mass is arsenic acid, which may either be preserved in that form or be dissolved in boiling distilled water.

REMARK....All the preparations of arsenic are deadly poison. The hydro-sulphurets are the best antidotes. A diluted solution of hydro-sulphuret of potash, soda, or lime, is therefore administered with success to persons who have been poisoned by arsenic. For the same reason sulphureous mineral waters may be given in such cases; oil, milk, butter, &c. which are too often resorted to, should never be employed, if a sulphuret or hydro-sulphuret can possibly be procured.

Arsenic acid united to different bases forms saline compounds, called ARSENIATES.

PROPERTIES OF ARSENIATES.

These salts are distinguished by being precipitated from their solutions, in the form of a yellow powder, by water holding sulphurated hydrogen gas in solution, or by hydro-sulphuret of ammonia. When heated in contact with charcoal powder they are decomposed, and arsenic sublimes.

METHODS OF OBTAINING ARSENIATES.

Arseniate of potash, soda, ammonia, or magnesia, may be obtained by saturating their carbonates with arsenic acid. Arseniate of lime is produced by pouring arsenic acid into lime-water. Arseniate of silver precipitates, if arsenic acid is dropt into a solution of silver. In a like manner arseniate of mercury is produced.

ARSENIOUS ACID.

PART XCI.

THE earliest chemists were embarrassed in the determination of the nature of the poisonous white substance known in commerce by the name of *white arsenic*. Subsequent experiments have shown that this substance is metallic arsenic oxygenated in the first degree. The name of *arsenious acid* is therefore given to it. It is sometimes found in nature in sublimed crystals, in volcanoes; and in masses, or in stalactites among the ores of arsenic, cobalt, bismuth, and nickel.

PROPERTIES OF ARSENIOUS ACID.

Arsenious acid is of a white colour; it possesses a weak sub-acid taste, which slowly manifests itself. Though of but a feeble acidity, it sensibly reddens the tincture of cabbage and litmus. If placed on burning coals or on a red-hot iron, it is volatilized in the form of a white vapour, which has a strong smell of garlic. Its specific gravity is 3.706. It is soluble in 80 parts of water, at 60° and in 16 at 212°. It sublimes at 283°. If heated in close vessels it vitrifies, and its specific gravity becomes 5.000 With phosphoric and boracic acids it fuses into glass. It decomposes the nitrates and the super-oxygenated muriate of potash. It unites with many of the earths and alkalies, and forms saline compounds.

METHODS OF OBTAINING ARSENIOUS ACID.

1. Pulverize arsenic, and put as much of it into a Florence flask as will fill it about one half or less. In-

troduce a little tow or cotton into the neck of the flask, and apply the heat of a lamp. A dense white smoke will be formed, and become precipitated on the internal sides of the flask. If the process be kept up till all the arsenic be oxydated (which may be known by introducing a wire into the flask for a moment, which will become covered with a white crust, if the sublimation be not completed) and the heat be then gradually augmented, the sublimed arsenious acid undergoes a sort of fusion, and an opaque white mass similar to that met with in commerce, is obtained.

2. The arsenious acid of the shops (or white arsenic) is chiefly obtained from arsenical ores of cobalt. These ores are thrown into a furnace resembling a baker's oven, with a long flue or chimney, either horizontal or winding, into which the fumes pass, and are condensed into a grayish or blackish powder. This is refined by a second sublimation in close vessels, with a little alkali to arrest the impurities. As the heat is considerable, it melts the sublimed arsenious acid into those opaque crystalline masses which are known in commerce by the name of white arsenic.

Arsenious acid united with different bases forms salts called ARSENITES.

PROPERTIES OF ARSENITES.

These combinations were formerly known by the fanciful appellation of *livers of arsenic.* They do not crystallize, but all of them appear in the form of a thick viscid yellow-coloured liquid, of a nauseous odour. They are decomposable by heat, and by the affusion of all the dense acids. They have been but very superficially examined, and are by no means sufficiently known to admit of a detailed description. They may be formed by dissolving arsenious acid in alkaline solutions.

TUNGSTIC ACID.

PART XCII.

THIS acid does not exist in nature in an uncombined state, but always united to lime *(tungstate of lime)* or with iron and manganese *(wolfram.)*

PROPERTIES OF TUNGSTIC ACID.

Tungstic acid appears in a pulverulent form, harsh to the touch. It is tasteless and insoluble in water. It is incapable of turning blue vegetable colours red, until it has been first rendered soluble by ammonia. It is of a yellow colour, which becomes blue on being exposed to the light. When put into muriatic acid with tin, zinc, or iron, it yields to them its oxygen, and hence the liquor becomes blue. It becomes also blue when boiled with sulphuric acid, and yellow with nitric, or muriatic, acid. Its specific gravity is about 6.12. It does not melt before the blow-pipe, but it becomes black when urged by the interior flame. With glacial acid of phosphorus it produces a transparent blue glass, if the inner part of the flame be directed on them, which loses its colour on being removed to the exterior part of the flame. It neutralizes alkalies, and is thus rendered soluble in water. Ammonia combined with it, or tungstate of ammonia, if dropped into lime water, instantaneously throws down a precipitate which is tungstate of lime.

METHODS OF OBTAINING TUNGSTIC ACID.

Let one part of powdered tungstate of lime be digested in three of nitric acid, till it acquires a yellow colour.

Decant the acid, and let the remaining yellow powder, after being washed in distilled water, be digested in liquid ammonia till it is rendered considerably whiter. This ammoniacal solution is then poured off, and the residual undecomposed part of the tungstate is once more treated with nitric acid as before. The acid being again separated it is again digested with liquid ammonia, and so on alternately till it is totally decomposed.

The ammoniacal solution is then decomposed by the addition of nitric acid; the tungstic acid becomes precipitated in the form of a white powder, which, after being washed, dried, and exposed to heat, assumes a yellow colour.

RATIONALE....On adding nitric acid to the ammoniacal solution, nitrate of ammonia is formed, and the tungstic acid becomes separated; but this last is not perfectly free from ammonia, it is therefore necessary to heat it, or to wash it in diluted nitric acid, by which means the adhering ammonia is either volatilized or neutralized, which then may be washed away by means of distilled water.

The tungstic acid may also be obtained from the mineral called wolfram, in which it is combined with iron and manganese, and frequently with silex, in the state of a yellow oxyd, as directed before. See Tungsten.

PROPERTIES OF TUNGSTATES.

These salts are very little known. Most of them, when dissolved in water, are decomposed by all the acids; these combinations occasion a precipitate, which is a triple compound, varying according to the acid employed.

METHODS OF OBTAINING TUNGSTATES.

Tungstate of potash, soda, or ammonia, may be formed by dissolving tungstic acid in the alkaline solutions. Tungstate of magnesia is obtained by boiling tungstic acid with carbonate of magnesia.

MOLYBDIC ACID.

PART XCIII.

PROPERTIES OF MOLYBDIC ACID.

MOLYBDIC acid is in the form of a yellowish white powder; it has an acid but metallic taste. Its specific gravity is 3.400. It remains fixed during an intense heat, as long as the crucible is covered, but the moment it is uncovered the acid rises unaltered in a white smoke. It is soluble in about 570 parts of water at a mean temperature. The solution reddens tincture of cabbage. Paper dipped in this acid becomes of a blue colour in the sun. Nitric acid has no action upon it. Muriatic acid and sulphuric acid dissolve it by the assistance of heat, and yield with it blue solutions. The attraction of the molybdena for oxygen in these acids is very feeble; for mere exposure to light, passing through it a current of hydrogen gas, or digesting it with any of the metals, changes its colour to a blue, by partially deoxydating it.

We are indebted to Mr. Hatchett for a thorough knowledge of the properties of this acid and all its combinations.

Scheele's method of obtaining molybdic acid consists in distilling about 25 or 30 ounces of diluted nitric acid from one ounce of native molybdena at five or more successive operations, that is to say, 4 or 6 ounces of the acid at a time. A great quantity of nitrous gas is obtained, and a white powder remains in the retort, which must be washed in distilled water to free it from the adhering foreign acid.

It may also be obtained by detonating molybdena in a red-heat with nitrate of potash. The residue left after detonation, when 4 parts of the salt to 1 of the metal have been employed, yields a colourless solution that contains the molybdate of potash, and which, upon a proper addition of water, lets fall the molybdic acid in the form of a white powder.

The union of molybdic acid with alkalies, earths, &c. forms salts termed MOLYBDATES.

PROPERTIES OF MOLYBDATES.

These salts are not better known than the last. A few with which we are acquainted have the property of giving a green colour to phosphate of soda and ammonia when melted with it; and occasion a blue precipitate with muriate of tin.

METHODS OF OBTAINING MOLYBDATES.

The super-molybdate of potash is the only salt that has been examined with tolerable accuracy. It may be produced by detonating one part of sulphuret of molybdena with three of nitrate of potash, dissolving the mass in water, filtering the solution and evaporating it. Sulphate of potash first crystallizes, but if sulphuric acid be dropt into the remaining solution, super-molybdate of potash is precipitated.

CHROMIC ACID.

PART CXIV.

CHROMIC acid exists in combination with various metals and earths. Combined with oxyd of lead, it forms the red lead ore of Siberia, called *chromate of lead.* It has been found united to iron, alumine, and silex, *(chromate of iron.)* Vauquelin has proved that it is the colouring matter of the emerald, &c. It probably exists in other gems.*

PROPERTIES OF CHROMIC ACID.

The chromic acid is of a ruby-red or rather orange yellow colour, and in crystals of a prismatic figure. These are soluble in water, and have a sharp, rough, pungent, and metallic taste. When mixed with filings of tin and muriatic acid, it becomes at first yellowish brown, and afterwards assumes a beautiful green colour. When mixed with a little ardent spirit and nitric acid, it immediately assumes a bluish green tinge, which preserves the same shade even after desiccation. Sulphuric ether gives it the same colour. If paper be dipped in chromic acid, and exposed for some days to the rays of the sun, it assumes a green colour, which does not change in the dark. Muriatic acid, heated in a retort with this acid, produces a strong effervescence, and oxygenated muriatic acid gas is evolved.

Chromic acid, mixed with a solution of the hydro-sulphuret of potash, is precipitated in the form of greenish brown flakes. *Tannin* precipitates it in flakes of a fawn colour. Heated by the blow-pipe on charcoal, it boils up,

* It is found united to iron in Chester County, Pennsylvania, and about 8 miles from Baltimore at a place called the *bare hills.* See the mode of analyzing it, page 149 of this volume. T. C.

and leaves an infusible green matter. Fused with phosphoric acid, or with borax, a vitreous globule is obtained of an emerald-green colour. Sulphuric acid, while cold, produces no effect upon it; but when heated it makes it assume a bluish-green colour. With a solution of nitrate of mercury, it gives a precipitate of a dark cinnabar red. With a solution of nitrate of silver, it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine red, but becomes purple by exposure to light. It unites with the alkalies, and forms crystallizable salts of a beautiful orange colour. It also unites with the earths and metallic oxyds, and forms compounds distinguished by the splendour of their colours.

METHODS OF OBTAINING CHROMIC ACID.

To obtain chromic acid, boil one part of the red lead ore of Siberia, reduced to an impalpable powder, with two of carbonate of potash and ten or twelve of water, for at least an hour. Then suffer the mixture to subside, decant and filter the super-natant fluid. The clear solution must then be evaporated and suffered to crystallize. When no more crystals can be obtained in this manner, the whole quantity of salt is to be dissolved in a sufficient quantity of distilled water, and pure nitric acid added to the saturation of the alkali. The solution now affords by evaporation crystals of a ruby colour, which are chromic acid.

On account of the scarcity of the minerals which contain this acid, the properties and methods of obtaining *chromates* are still unknown. *(See Appendix, No. 35.)*

COLUMBIC ACID.

PART CXV.

COLUMBIC acid exists in the new discovered ore called columbate of iron.

PROPERTIES OF COLUMBIC ACID.

Columbic acid appears in the form of a white pulverulent substance, whose colour does not become changed when boiled in nitric acid. It is soluble in sulphuric and muriatic acid. The solution in sulphuric acid when mingled with water, deposits a white precipitate, which, when suffered to dry, acquires first a blue and then a gray colour. All the acid solutions are decomposable by alkalies. Columbic acid has scarcely any perceptible flavour, nor does it appear to be soluble in water; but when moistened with this fluid, and placed in contact with litmus paper, it very soon reddens it. It expels the carbonic acid from carbonated alkalies, and forms salts with potash and soda, which are colourless, soluble in water, permanent in the air, and decomposable by nitric acid. Dissolved in water they form a precipitate, when mingled with solutions of tungstate and molybdate of potash, with cobaltate of ammonia, and alkaline solutions of iron. Columbic acid does not combine with ammonia, nor does it unite with sulphur, by fusion. It forms a purplish blue glass with phosphate of ammonia. For a fuller account of this acid, we refer our reader to Mr. Hatchett's paper in the Philosoph. Transactions, 1802, p. 1. p. 40. The method this philosopher made use of for separating this acid from its natural combination has been noticed already....See Columbium.

ACETOUS ACID.

PART CXVI.

THIS acid exists combined with much mucilage and extractive matter, and some portion of acidulous tartrite of potash in common vinegar. When freed from them, it is called acetous acid, or distilled vinegar.

PROPERTIES OF ACETOUS ACID.

Acetous acid is a perfectly colourless fluid, of an agreeable acidulous odour, and pleasant sour taste, though frequently (at least when not carefully prepared) it possesses more or less of an empyreumatic flavour. It acts on almost all the metallic substances. Its combinations are attended with a variety of important phenomena, and afford products of the greatest utility in the arts, &c. Its affinity to earths, alkalies, and metallic oxyds, is inferior to that of the sulphuric, muriatic, and nitric acids.

Acetous acid is formed by the fermentation of wine, on which account it is called vinegar. However, wine is not indispensably necessary for its production, as it is found in the urine of animals, &c. The vinegar produced during fermentation is far from being pure acetous acid, but may be obtained so by distillation. For this purpose take the strongest vinegar possible, and having introduced it into a glass retort, place it in a sand-heat, or rather in a water-bath. Adapt to the retort a large receiver, and lute the joinings. Then apply a gentle heat, and increase it gradually, taking care to cool the receiver with cloths soaked in water. The first portion which passes over is an aqueous fluid; but the acetous acid soon ascends. This is what is called distilled vinegar.

The combinations of acetous acid with different bases form salts, called ACETITES.

PROPERTIES OF ACETITES.

Acetites are decomposable by heat; the acetous acid is either disengaged unaltered, or decomposed. They are likewise decomposed by the affusion of sulphuric acid.

METHODS OF OBTAINING ACETITES.

Acetite of potash, soda, barytes, strontia, or lime, may be obtained by neutralizing the carbonates of these alkalies with acetous acid, evaporating the solution and crystallizing it. Acetite of lime or magnesia may be obtained in a direct manner. Acetite of silver is produced by dropping acetite of potash into a solution of nitrate of silver. Acetite of mercury is produced in a similar manner from nitrate of mercury, and acetite of potash. Acetite of iron, lead, zinc, and nickel, may be produced by dissolving these metals in acetous acid, evaporating the solutions and suffering them to crystallize.

ACETIC ACID.

PART XCVII.

THE acetous acid, deprived of part of its carbon, changes its nature; it acquires new properties, and then constitutes what is called acetic acid. The difference between the acetous and acetic acid does not depend, as was formerly supposed, on a different degree of oxygenation, but on the different proportions of carbon which enter into its composition.

PROPERTIES OF ACETIC ACID.

Acetic acid has a more pungent, sour smell than acetous acid. Its odour is so penetrating, that when very concentrated it is impossible to support it for any length of time: it is even caustic, and capable of corroding the skin. It is extremely volatile.

METHOD OF OBTAINING ACETIC ACID.

Take one part of acetate of potash, put it into a tubulated retort, lodged in a sand-heat, and pour gradually upon it half its weight of sulphuric acid. A violent action takes place, and part of the acetic acid becomes liberated in the form of white vapours. After the spontaneous action has ceased, distil with a gentle heat, and acetic acid will be obtained in a considerable quantity.

OXALIC ACID.

PART XCVIII.

PROPERTIES OF OXALIC ACID.

OXALIC acid is always concrete; its crystals are colourless quadrilateral prisms, having their sides alternately broad and narrow, and terminating in two-sided summits, of a very acid taste. It is particularly distinguished by its strong attraction to lime, which is superior to that of any other acid. It is not altered on exposure to air. It acts on most of the metals. Exposed to heat it becomes decomposed into carbonic acid, and carbonated hydrogen gas. It contains more oxygen than any other vegetable acid. Oxalic acid is soluble in its own weight of water at 212, and in about 2 parts of water at 65°. It reddens vegetable blues readily. Boiling alcohol dissolves somewhat more than half its weight, and at an ordinary temperature a little more than one-third. It is soluble in the muriatic and acetous acids.

METHOD OF OBTAINING OXALIC ACID.

Oxalic acid is generally prepared by oxygenizing sugar, in the following manner: Put one part of white sugar into a retort, and pour over it four parts of nitric acid, of about 1.567 spec. grav. adapt a receiver, and make the solution boil. When the fluid in the retort acquires a brown colour, add three parts of acid more, and continue the boiling till it again becomes brown; then add two parts more of acid, and continue the heat till the red fume almost disappears. Having done this, suffer the mixture to crystal-

lized. After having removed the obtained crystallized acid, the residue may again be treated in a similar manner as before, until no more crystals are obtained. It may then be purified by dissolving it in water, and re crystallizing it repeatedly. [It is composed of 64 oxygen, 32 carbon, and 4 hydrogen. DAVY.]

Oxalic acid united to alkalies, earths, &c. forms salts, called OXALATES.

PROPERTIES OF OXALATES.

The soluble salts formed by the union of oxalic acid with different bases are decomposable by lime-water; the precipitate produced is soluble in acetous acid. Most of the alkaline oxalates are capable of combining with an excess of acid. The earthy oxalates are in general nearly insoluble; they are, however, all decomposable by a red heat.

METHODS OF OBTAINING OXALATES.

Oxalate of ammonia may be obtained by carefully saturating oxalic acid, dissolved in water, with carbonate of ammonia, and suffering the fluid to crystallize as soon as a pellicle appears. Oxalate of potash, or soda, may be obtained in a similar manner. Oxalate of lime is produced by letting oxalic acid fall into lime-water; the salt instantly becomes precipitated. Oxalate of strontia is formed by mingling a solution of oxalate of potash with nitrate of strontia; the oxalate of strontia precipitates instantly. Oxalate of barytes may be produced by dissolving barytes in oxalic acid to saturation.

TARTAREOUS ACID.

PART XCIX.

TARTAREOUS acid exists in the juices of many vegetables, generally combined with lime.

PROPERTIES OF TARTAREOUS ACID.

Tartareous acid appears in the form of tabular crystals. Its specific gravity is 1.5962. Its taste is exceedingly sour. It is permanent in the air. It readily dissolves in water. The solution is not decomposed by evaporation nor on exposure to air, unless very diluted. It takes lime from the nitric, muriatic, phosphoric, and acetous acids. It has a strong tendency to unite to potash. In one proportion it forms a soluble salt (tartrite of potash) but when the acid is in excess it forms a salt of difficult solubility (acidulous tartrite of potash.) It is on this account that the presence of tartareous acid in any solution may easily be detected. It is decomposable by heat. It may be changed into oxalic acid, by repeated distillation with nitric acid. Tartareous acid is composed, according to Fourcroy, of 10.5 oxygen, 19.0 carbon, 15.5 hydrogen.

METHODS OF OBTAINING TARTAREOUS ACID.

To obtain tartareous acid dissolve thirty-two parts of acidulous tartrite of potash* in water, and throw chalk into it gradually till it is completely saturated, a precipitate

* That is, Cream of Tartar.

will be formed, which is *tartrite of lime;* decant the fluid, and put the tartrite of lime into a matrass, pour over it nine parts of sulphuric acid and five of water; digest the whole for six hours, taking care to stir it from time to time; the tartareous acid will then remain free, and may be separated, by means of cold water, from the sulphate of lime which has been formed, and crystallized by suffering it to evaporate slowly.

REMARK....To ascertain whether the tartareous acid contains sulphuric acid, let fall into it a few drops of acetite of lead: if the precipitate, which is formed, be entirely soluble in acetous acid, the fluid contains no sulphuric acid; if it is not soluble, sulphuric acid is present: to free it from this, the fluid must again be digested over another quantity of the tartrite of lime.

The salts formed by means of tartareous acid are called TARTRITES. *(See Appendix, No. 36.)*

PROPERTIES OF TARTRITES.

All the tartrites are decomposable by a red heat, the basis is left behind in the state of a carbonate. They are decomposable by sulphuric acid. They are capable of combining with an excess of acid, forming salts, called super-tartrites. Most of them are also capable of combining with another base, in order to form triple salts.

METHODS OF OBTAINING TARTRITES.

Tartrite of potash, soda, or ammonia, is formed by dissolving the carbonates of these alkalies in tartareous acid, to saturation, and evaporating the solutions as directed so frequently before. Tartrite of strontia is precipitated by mingling a solution of nitrate of strontia with a solution of tartrite of potash. Tartrite of potash and lime is produced by dropping tartrite of potash into lime-water. Tartrite of potash and barytes, and tartrite of potash and strontia, are formed in a similar manner. Tartrite of potash and soda is produced by neutralizing a solution of acidulous tartrite of potash with carbonate of soda. Tartrite of potash and ammonia is obtained by

mixing a solution of acidulous tartrite of potash with carbonate of magnesia. Tartrite of silver is produced by dropping a solution of nitrate of silver into a solution of acidulous tartrite of potash. Tartrite of mercury is precipitated by letting fall tartareous acid into a solution of nitrate of mercury. In a similar manner tartrite of lead and tartrite of bismuth are formed. Tartrite of iron and tartrite of copper are produced by decomposing in a like manner, a solution of sulphate of copper, or sulphate of iron.

CITRIC ACID.

PART C.

CITRIC acid exists in the juice of lemons and oranges; in unripe grapes, cranberries, bilberries, and a variety of other sour fruits.

PROPERTIES OF CITRIC ACID.

Citric acid crystallizes in the form of rhomboidal prisms, which suffer no alteration from exposure to air. They are easily dissolved by water, and excite a very sour taste, which, when diluted, is exceedingly pleasant. One part of boiling water dissolves two of citric acid. It acts upon iron, zinc, tin, lead, and various other metals. Sulphuric acid chars it, and forms vinegar. Treated with nitric acid it becomes converted into oxalic and acetic acid. Exposed to a red heat it becomes decomposed into carbonic acid, and carbonated hydrogen gas, and a little charcoal remains behind.

METHOD OF OBTAINING CITRIC ACID.

Saturate any quantity of boiling lemon juice, by adding to it, gradually, chalk, in small quantities, until the effervescence ceases, on adding to it a new portion of chalk. During this process a white precipitate will be formed, and fall down to the bottom, consisting of citric acid and lime (citrate of lime.) Separate this precipitate by transferring the whole on a strainer, and pour water over it till this fluid passes tasteless. Transfer the washed precipitate into a matrass, or other convenient vessel, and pour over it as much sulphuric acid as will neutralize the chalk employed, having previously diluted the acid with

six times its weight of water. Boil the whole about half an hour, agitating it with a wooden spatula during the whole time, and then pour it on a filter, taking care to return the fluid, which passes through, back upon the filter until it becomes perfectly clear. Having done this, evaporate it in a shallow vessel to the consistence of a thin syrup, and leave it to crystallize undisturbed The crystals obtained are citric acid; in order to obtain them in a state of purity they must be re-dissolved, the solution filtered, and re-crystallized repeatedly.* Four parts of chalk require in general, for saturation, 94 parts of lemon juice. The citrate of lime produced amounts to about $7\frac{1}{2}$ parts. To decompose this, nearly 20 parts of sulphuric acid are necessary.

The combination of citric acid with different bases, forms the salts called CITRATES.

PROPERTIES OF CITRATES.

All the salts consisting of citric acid, when dissolved in water, are decomposable by the addition of tartareous and oxalic acid. They are likewise decomposed by sulphuric, nitric and muriatic acids. A solution of barytes, mingled with a solution of citrate of potash, soda, or ammonia, produces an insoluble precipitate.

METHODS OF OBTAINING CITRATES.

Citrate of soda, ammonia, lime, potash, or magnesia, may be formed by dissolving the carbonates of these substances in citric acid, and evaporating the solution. The two latter do not crystallize. Citrate of barytes is precipitated by adding a solution of barytes to citric acid. Citrate of strontia is produced by dropping a solution of nitrate of strontia into citrate of ammonia. Citrate of iron and citrate of zinc may be formed by dissolving these metals in citric acid, and subsequent evaporation and crystallization. Citrates of silver, mercury, and lead, are obtained in a similar manner from the oxyds of these metals.

* Mr. Coxwell, who has established a manufacture of citric acid, prepares it in a state of absolute purity; and at so cheap a rate as was formerly thought impossible to procure it.

MALIC ACID.

PART CI.

THIS acid is found ready formed in the juice of unripe apples, and in those of barberries, elderberries, gooseberries, plums, and the common house-leek.

PROPERTIES OF MALIC ACID.

Malic acid is incapable of crystallizing, but appears always in the liquid state, of a reddish brown colour. Its taste is an unpleasant sour. If left exposed to the air, it gradually undergoes a spontaneous decomposition. Nitric acid converts it into oxalic acid. It forms precipitates in the solution of nitrate of mercury, lead, and silver.

METHODS OF OBTAINING MALIC ACID.

1. Take the juice of apples, saturate it with potash, and then add a solution of acetite of lead till it no longer occasions a precipitate; wash this precipitate, which is malate of lead; pour over it sulphuric acid till the liquor acquires an acid taste without any mixture of sweetness, and filter the whole, in order to separate the malic acid from the sulphate of lead which is formed.

2. Malic acid is also obtained by adding to the expressed juice of house-leek, a solution of acetite of lead, till no further precipitate ensues. The precipitate, after being washed, may be decomposed by sulphuric acid as before.

3. Malic acid may likewise be produced by distilling equal quantities of nitric acid and sugar, till the solution acquires a brown colour. The sugar is thus partly converted into oxalic, and partly into malic, acid. The oxalic acid may be separated by mingling the solution with lime-water, until no further precipitate ensues; the malic acid is then left behind. In order to obtain it in a pure state neutralize it with lime, filter the solution, and mix it with alcohol. A coagulation now takes place; for the water separates, and the malic acid, united to the lime, may be obtained by filtration. Having done this, let it be dissolved in water, and add to it a solution of acetite of lead until no further precipitate ensues. This precipitate, which is malate of lead, may be decomposed by sulphuric acid, as before directed.

Malic acid has been lately detected in the acid liquid obtained from ants. When this acid liquid is saturated with lime, and mingled with acetite of lead, a precipitate is obtained which is malate of lead, which may be decomposed by the affusion of sulphuric acid.

Malic acid united to different bases, forms the salts called MALATES.

PROPERTIES OF MALATES.

These salts are little known, they have been examined superficially by Scheele only. The malates of potash, soda, and ammonia, are deliquescent. Malates of lime, barytes, and magnesia, are very insoluble.

METHODS OF OBTAINING MALATES.

Malate of potash, soda, ammonia, lime, or barytes, may be formed by dissolving these alkalies in malic acid, and evaporating the solutions.

GALLIC ACID.

PART CII.

GALLIC acid exists in the gall-nut, an excrescence growing on some species of oaks, in the husk of nuts, in oak bark, and in all those vegetables commonly called astringents.

PROPERTIES OF GALLIC ACID.

Gallic acid appears in the form of minute, brilliant, colourless plates. Its taste is sour, and austere or astringent. It strongly reddens blue vegetable colours. It is soluble in about 10 parts of cold, and in three of boiling water. It is likewise soluble in alcohol. It has a peculiar disagreeable odour when heated. It is not altered by exposure to air. Exposed gradually to a gentle heat, it sublimes without alteration; but if exposed to a strong heat, quickly applied, it becomes decomposed into carbonic acid, and carbonated hydrogen gas. It has a strong tendency to unite with metallic oxyds. With the red oxyd of iron it produces a deep black precipitate. This combination is the basis of ink and black dyes. It precipitates gold, copper, and silver, brown; mercury, orange; bismuth, yellow: and lead, white. It has no action on the oxyds of platina, tin, zinc, cobalt, manganese, and arsenic.

METHODS OF OBTAINING GALLIC ACID.

For the following method of obtaining gallic acid we are indebted to Mr. Fiedler.*

* Nicholson's Journal, vol. I. No. 3. p. 236.

1. Dissolve two ounces of alum of commerce in water, and precipitate the solution, by letting fall into it a solution of potash; wash the precipitate well, and transfer it into an aqueous infusion of gall-nuts (obtained by infusing 1 oz. of galls into 16 of water, and evaporating the infusion to one half) agitate the mixture frequently during the course of 24 hours, and transfer it on a filter. The fluid which passes through the filter is gallic acid; it may be obtained in the form of needle-shaped crystals by evaporating it slowly, till a pellicle appears, and then letting it stand undisturbed.

2. Gallic acid may also be obtained, according to Scheele, in the following manner: Reduce a pound of nut-galls to powder, and pour upon it six pounds of distilled water: Leave this mixture to macerate for the space of 15 days at a temperature of 68° or 70°. Then filter this liquor; and after the filtration, expose it in a vessel of glass or stoneware, to evaporate slowly in the air. During this evaporation, which may be continued during two or three months, the gallic acid will be deposited in crystals, on the sides and bottom of the vessel, and on the inferior surface of a pellicle which will have formed over the mixture. At the end of this period, pour off the liquor. Then dissolve whatever remains in the vessel in alcohol. This last solution, evaporated, will afford the gallic acid in crystals.

3. Gallic acid may likewise be obtained by exposing powdered nut-galls in a retort to a moderate heat. The acid by this means sublimes, part condenses in small white crystals, and part is obtained in a fluid form, from its combination with a portion of water contained in the galls.

Remark....This process requires a great deal of precaution; the fire must be gradually raised, and slackened the moment coloured drops fall from the beak of the retort, otherwise the whole product becomes dissolved again, and is lost.

Gallic acid, united to different bases, forms salts called gallates. They have not hitherto been examined.

SUCCINIC ACID.

PART CIII.

SUCCINIC acid, or salt of amber, exists in a bituminous substance, called amber, which is of a yellow colour, takes a fine polish, and is electric. It is found principally on the sea-coast in Prussia.

PROPERTIES OF SUCCINIC ACID.

Succinic acid exists in a solid form. Its crystals are colourless, four-sided, oblique plates, which are permanent in the air. It has a strong acid taste. It is soluble in 24 parts of cold, and in two of boiling, water. It is soluble in hot alcohol. It may be volatilized by heat, but suffers a partial decomposition.

METHOD OF OBTAINING SUCCINIC ACID.

Fill a matrass half full of amber, lute to it an alembic, and distil with a gradual heat, till drops of oil fall from the beak of the alembic. Then separate the solid acid which has sublimed, dissolve it in water, filter the solution, and suffer it to crystallize. Repeat these latter operations till the salt is nearly colourless; or this trouble may be saved by abstracting from it a small quantity of nitric acid, which renders it a beautiful white: one drachm of nitric acid is sufficient to 1oz. of succinic acid of commerce.

The salts formed by succinic acid are termed SUCCINATES. Their properties are very little known.

METHOD OF OBTAINING SUCCINATES.

Succinate of potash, soda, ammonia, or lime, may be obtained by dissolving these alkalies to saturation in succinic acid, evaporating the solution, and setting it aside to crystallize. Succinate of magnesia is obtained in a similar manner, but it does not crystallize.

BENZOIC ACID.

PART CIV.

BENZOIC acid exists in considerable quantity in the concrete resin, termed benzoin; in Peruvian balsam; in balsam of Tolu, liquid storax, and other odoriferous substances of a similar nature. It also exists in human urine, and in that of cows; in the blood; and the albumen of eggs; in glue, silk, wool, sponge, and in mushrooms.*

PROPERTIES OF BENZOIC ACID.

Benzoic acid exists in the form of fine white light crystals, permanent in the air, which are not brittle, but rather ductile. Its taste is not very predominant, but irritating, pungent, and vivid. When perfectly pure it is totally void of odour. It is sparingly soluble in cold, but abundantly in hot water, and very soluble in alcohol, and in sulphuric, nitric, and acetic acids; but it is separable again by the admixture of water. It volatilizes in a moderate heat. It burns when placed on ignited charcoal, and detonates with nitrate of potash.

METHODS OF OBTAINING BENZOIC ACID.

Benzoic acid is best obtained by boiling repeatedly four parts of powdered benzoin, a resin obtained from the storax benzoin of strontia, with one of lime, or with four of carbonate of soda, in an earthen pot with 20 parts of water, filtering the solution, and adding to it sulphuric or muriatic acid, till no further precipitate ensues. The

* Annales de Chimie, XXXVI, p. 272.

precipitate obtained after being washed in water, is benzoic acid. It may be purified by repeated solutions, filtrations, and crystallizations.

Benzoic acid may also be obtained by exposing benzoin in an earthen pot to a gentle heat, and covering the crucible with a cone of blotting paper. The acid sublimes, and affixes itself to the paper. It may be also extracted from storax and all the other balsams, particularly those of Tolu or Peru, and from the urine of children, and herbiferous animals.

The salts which this acid forms are called BENZOATES. Their properties are little known. They generally form feather-shaped crystals, and are soluble in water.

METHOD OF OBTAINING BENZOATES.

Benzoate of potash, soda, ammonia, barytes, or lime, may be obtained by neutralizing benzoic acid with these alkalies, evaporating the solution, and suffering them to crystallize. Benzoate of alumine and magnesia are produced in a similar manner.

CAMPHORIC ACID.

PART CV.

PROPERTIES OF CAMPHORIC ACID.

CAMPHORIC acid exists in the form of white parallelopipedes which effloresce in the air. Its taste is acid, slightly, and somewhat bitter. It strongly reddens vegetable blues. It is very volatile; it is sparingly cold; soluble in water, more soluble in alcohol, in sulphuric, nitric, and muriatic acid, and in volatile and fat oils. It is fusible, and sublimes by heat. To obtain camphoric acid, put into a retort one part of camphor and eight of nitric acid, distil the mixture, and repeat it three times on the same residue with a like quantity of acid; after the last distillation is accomplished, crystals will be found in the retort, which are camphoric acid; re-dissolve them in boiling water, and suffer it to crystallize.

The salts formed by camphoric acid with different bases are denominated CAMPHORATES.

PROPERTIES OF CAMPHORATES.

All the camphorates known are easily decomposable by heat, the acid subliming; urged with a blow-pipe they burn with a blue flame. Their taste is a saline bitter.

METHODS OF OBTAINING CAMPHORATES.

Camphorate of potash, soda, or ammonia, may be obtained by neutralizing these alkalies with camphoric acid, evaporating the solution and suffering it to crystallize. Camphorate of lime and alumine may be produced in a similar manner.

MUCOUS, OR SACCHO-LACTIC ACID.

PART CVI.

THIS acid was discovered by Scheele, who obtained it by treating sugar of milk with nitric acid. Hence he called it saccho-lactic acid.

PROPERTIES OF MUCOUS ACID.

Mucous acid exists in the form of a white gritty powder. It is soluble in eighty times its weight of boiling water, but more soluble in alcohol. Its taste is slightly acid, but it sensibly reddens tincture of cabbage. It scarcely acts upon any of the metals. It forms soluble salts with potash, soda, or ammonia; but insoluble compounds with most of the rest of the alkalies and earths.

METHODS OF OBTAINING MUCOUS ACID.

Take one part of gum arabic reduced to powder, put it into a retort, and pour over it two parts of nitric acid; heat the mixture gradually, keep it boiling for about a quarter of an hour, and then suffer it to cool; a white powder will separate, which, after being washed, is mucous acid.

Mucous acid may be obtained, by treating sugar of milk with nitric acid, in a similar manner.

The compounds formed of mucous acid have been but little investigated.

SUBERIC ACID.

PART CVII.

SUBERIC acid exists in *cork*, a substance well known.

PROPERTIES OF SUBERIC ACID.

Suberic acid is not crystallizable, but it may be produced in the solid form of a powder, or thin pellicles. It is volatilized by heat. Suberic acid has a sharp, acid, bitterish taste. It acts strongly upon the throat, and excites coughing. It strongly reddens vegetable blues, and has the peculiar property of turning the blue colour of a solution of indigo in sulphuric acid, of the nitrate of copper, and of the sulphate of copper to green, and gives a yellow colour to the solution of green sulphate of iron, and to the solution of sulphate of zinc. It is difficultly soluble in cold, but easily soluble in boiling, water. When heated, it first fuses, then becomes dry, and at last sublimes entirely.

METHOD OF OBTAINING SUBERIC ACID.

Introduce one part of cork cut into small pieces into a retort, and pour upon it six of nitric acid, distil the mixture with a gentle heat till no more nitrous gas appears. Then pour the contents into a basin, and evaporate it till it acquires the consistence of honey, and a pungent suffocating vapour arises; then add to it twice its bulk of boiling water, heat it gently, and pour it on a filter. The fluid which passes, when cooling, deposits a precipitate, which must be separated; the fluid is then evaporated to dryness, and the product obtained is suberic acid.

The union of suberic acid with different bases constitutes the salts called SUBERATES. They have no marked properties except a bitter taste.

PRUSSIC ACID.

PART CVIII.

THIS acid derives its name from the pigment called Prussian blue, of which it forms a component part.

PROPERTIES OF PRUSSIC ACID.

Prussic acid exists in the form of a colourless fluid. It has a strong odour, greatly resembling that of peach-tree flowers, or of bruised bitter almonds. Its taste is sweetish, pungent, and somewhat acrid. It is very volatile and inflammable when in the state of vapour or gas. It does not redden the most delicate vegetable blues, and unites difficultly with alkalies and earths in the direct way. It is easily decomposable by light, heat, or oxygenized muriatic acid at high temperatures; it becomes converted into ammonia, carbonic acid, and carbonated hydrogen gas. It does not act upon any of the metals, but readily unites with most of their oxyds, with which it forms highly insoluble compounds. It has a great tendency to form triple compounds with alkalies and metallic oxyds, and in that state it decomposes all metallic salts, and hence it is one of the most important re-agents of the chemist.

METHOD OF OBTAINING PRUSSIC ACID.

The process made use of by chemists for obtaining prussic acid is the following: put into a glass matrass two parts of pulverized Prussian blue, one part of red oxyd of mercury, and six parts of water; boil this mixture

for half an hour, agitating it frequently, then filter it, and pour over the residuum two parts more of boiling water, and having united the liquors, evaporate the whole to obtain crystals.

RATIONALE....The prussic acid quits the oxyd of iron to unite to the oxyd of mercury, with which it forms prussiate of mercury, which can neither be decomposed by acids nor alkalies. In order to disengage from it the prussic acid, dissolve it in water, or take the liquor above mentioned, not concentrated: pour the quantity obtained in the preceding experiment into a bottle containing about an ounce of iron filings, add nearly three ounces of concentrated sulphuric or muriatic acid, and shake it well for some minutes: the mixture now becomes black, for the iron unites to the oxygen of the mercury, and combines with the acid. Leave the fluid at rest, and then decant it, and put it into a retort placed on a sand-bath; adapt to the retort a receiver, containing a little distilled water, to absorb the acid, and carefully lute all the joinings. By the help of a gentle heat, the prussic acid, being more volatile than water, will pass over first: and when about a fourth of the liquor has passed, stop the operation.

The liquor which passes contains a little sulphuric acid: to free it from this acid, distil it again, with a very gentle heat, from pulverized chalk, and prussic acid will be obtained in the greatest purity.

Prussic acid may be obtained by distilling two parts of prussiate of potash with one of sulphuric acid, previously diluted with an equal quantity of water; the prussic acid becomes disengaged, and is absorbed by the water previously put into the receiver; or by distilling bitter almonds, the kernels of peach-stones, or the leaves of the cherry-laurel (lauro cerasus Lin.) with water.

The combination of prussic acid with different bases forms salts called PRUSSIATES.

PROPERTIES OF PRUSSIATES.

These salts have been little examined, probaby on account of the difficulty which attends their formation,

and the spontaneous decomposition they suffer. All that is known concerning them is that they are very easily decomposed by all acids, and also by a mere exposure to vivid light, or to a heat of about 110°. All the metallic prussiates are insoluble, except prussiate of mercury and manganese. These compounds are not decomposable by acids. The triple prussiates are the salts which have been most particularly examined, on account of the important action they exercise upon other bodies.

METHODS OF OBTAINING PRUSSIATES.

Prussiate of potash and iron. The best methods of preparing this important salt are the following:

Prepare pure potash as directed before. See Potash.

Dissolve it in five times its weight of water, and pour this solution into a glass receiver, placed in a sand-bath, heated to 170° or 180°, and then gradually add the best Prussian blue in powder, injecting new portions, as the former becomes discoloured, and supplying water as fast as it evaporates, until the last added portions of Prussian blue are no longer discoloured; then increase the heat to boiling, and continue it for half an hour. Filter the ley thus obtained, and saturate it with sulphuric acid moderately diluted; a precipitate will appear: when this ceases, filter off the whole, and wash the precipitate.

Evaporate the filtered fluid to about one quarter, and set it aside to crystallize; after a few days, yellowish crystals of a cubic or quadrangular form will be found mixed with some sulphate of potash and oxyd of iron; pick out the yellowish crystals, lay them on blotting paper, and re-dissolve them in four times their weight of cold water, to exclude the sulphate of potash. Having done this, essay a few drops of this solution with barytic water to see whether it contains any sulphuric acid, and add some barytic water to the remainder if necessary; filter off the solution from the sulphate of barytes, which will have precipitated, and set it by to crystallize for a few days, that the barytes, if any should remain, may be precipitated. If the crystals now obtained be of a pale yellow colour, and discover no bluish streaks, when sprinkled over with muriatic acid, they are fit for use;

but if they still discover bluish or green streaks, the solution and crystallization must be repeated.

These crystals must be kept in a well-stopped bottle, which, to preserve them from the air, should be filled with alcohol, as they are insoluble in it.

Another good method of preparing this salt has been lately given by Mr. W. Henry.* It consists in first forming a triple prussiate of barytes, and adding it in crystals to a solution of carbonate of potash, till the solution no longer restores the colour of reddened litmus paper. After digesting the mixture for half an hour, filter the liquid and evaporate it gently. The triple prussiate of potash crystallizes.

Triple prussiate of potash, when pure, forms fine transparent crystals of a yellow colour: they have the form of cubes or parallelopipeds, and contain, when prepared according to the first method, 0.24 parts of oxyd of iron.

Remark....This salt or its solution in water, is the most useful test ever discovered, for by means of it we are enabled to ascertain whether any metallic substance is present in any solution; for it precipitates all metals (*platina* excepted) in the form of a coloured powder, from the colour of which we may learn what metal was present in the solution, and from the proportion, its respective quantity. But in order to be accurate in this respect, the test employed must itself either be free from iron, or the quantity it contains must be known. The first object has hitherto failed, the latter may be accomplished in the following manner: Take 100 grains of the triple prussiate, obtained as before, heated to redness for half an hour in an *open* crucible: it will thus be consumed, and the iron will remain in the state of a reddish brown magnetic oxyd; this must be weighed, and the weight noted down. This oxyd is half the weight of the Prussian blue which the test would afford: its weight must therefore be subtracted from that of the precipitate formed by the test. Hence the weight of the crystals, in a given quantity of the solution, should be noted, that the quantity employed in precipitation may be known. Care must be taken to continue the heat till the oxyd of iron becomes brown; for while it is black it weighs considerably more than it should.

* Nicholson's Journal, IV. 31.

Prussiate of lime and iron may be obtained by boiling two parts of Prussian blue in about 56 of lime water, for about $\frac{1}{4}$ of an hour, till the prussic acid is neutralized with the lime, which will be known by its not altering the colour of turmeric paper. *Prussiate of barytes and iron* is best prepared according to Henry's method, by adding Prussian blue to hot barytic water, till a new portion added ceases to be discovered; the solution may then be filtered, evaporated and crystallized. *Prussiate of strontia and iron* is produced in a similar manner. *Prussiate of iron*, or Prussian blue, is prepared by igniting, with a moderate heat, 3 parts of dried blood and 2 of carbonate of potash. From this mass a ley is obtained by the affusion of water. This is mingled with a solution of one part of sulphate of iron of commerce, and two of alum; a green precipitate is formed, which, when washed with diluted muriatic acid, assumes a beautiful blue colour.

LACTIC ACID.

PART CIX.

THIS acid exists in the *whey* of milk.

PROPERTIES OF LACTIC ACID.

LACTIC acid is capable of existing in the solid state; but it greatly attracts moisture, and becomes liquid. It has a sour taste. It strongly oxydates iron, zinc, copper, and various other metals.

METHOD OF OBTAINING LACTIC ACID.

Take any quantity of whey, evaporate it very slowly to one eighth, filter it, and then add to it lime-water till no further turbidness appears. Filter the mixture again, and let fall into the fluid, diluted with water, a solution of oxalic acid, till it produces no further cloudiness. Then filter it and evaporate the fluid to the consistence of syrup, and mingle with it alcohol. Having done this, separate the fluid again by filtration, add to it a small quantity of water, put it into a retort, and distil off the spirit; the remaining water then contains the lactic acid in a pure state.

The combination of lactic acid with different bases forms salts called LACTATES. They have not as yet been examined with accuracy.

SEBACIC ACID.

PART CX.

PROPERTIES OF SEBACIC ACID.

SEBACIC acid exists in a concrete form. It crystallizes in needles. It is void of odour. Its taste is slightly acid. When heated it liquifies like tallow, and is not volatile. It is soluble in cold water. Boiling water dissolves it very readily. It is also soluble in alcohol. It precipitates the acetites and nitrates of silver, mercury, and lead and the acetites of lead and mercury. It does not precipitate lime-water, barytic water, or strontian water.

METHOD OF OBTAINING SEBACIC ACID.

Distil hog's lard, wash the product with hot water, and drop into it a solution of acetite of lead, till it occasions no further precipitate. Collect this precipitate, wash it, and dry it. Having done this, pour over it sulphuric acid and heat it; a substance resembling fat will then appear on the surface. This being collected, dissolved in boiling water, and suffered to cool, crystallizes, and is sebacic acid.

The combination of sebacic acid with different bases, forms the salts called SEBATES. Sebate of potash, soda, ammonia, or lime, are crystallizable.

LACCIC ACID.

PART CXL

THIS acid has been discovered by Dr. Pearson, in a wax-like substance called *white lac*, of Madras, formed by certain insects of the coccus tribe. By exposing this substance to such a degree of heat as was just sufficient to liquefy it, a fluid was obtained to which the doctor has given the name of laccic acid.

PROPERTIES OF LACCIC ACID.

Laccic acid naturally exists in the fluid state. Its specific gravity Dr. Pearson found to be 1.025 at 60°. It strongly reddens paper stained with litmus. It has a saline bitter taste. When heated, it smells precisely like newly-baked hot bread. On suffering it to be exposed to the atmosphere it becomes turbid.

It rises in distillation. It decomposes with effervescence the carbonates of lime and soda. It renders the nitrate and muriate of barytes turbid. It assumes a green colour with lime-water, and a purplish colour with sulphate of iron; and precipitates sulphuret of lime white; tincture of galls, green; acetite of lead, reddish; nitrate of mercury, whitish; and tartrite of potash in the same way as tartareous acid does, except that the precipitate is insoluble in potash.

BOMBIC ACID.

PART CXII.

THE phalæna, or moth of the silk-worm, particularly when in the state of a crysalis, contains, in a reservoir situated near the anus, an acid liquor, said to be of a peculiar nature. This acid is obtained by squeezing the juice of the crysalis through a cloth, and precipitating the mucilage by the admixture of alcohol. Or, it may be obtained by digesting the crysalis in alcohol, mixing the infusion with a little water, and subtracting the alcohol by a gentle heat. The acid thus obtained is of an amber colour. It affords prussic acid when distilled with nitric acid. Its other properties and combinations are hitherto little known. An acid analogous exists in several caterpillars, in that of the willow, and in other insects.

AMNIOTIC ACID.

PART CXIII.

VAUQUELIN and Buniva have discovered a peculiar acid in the liquor of the amnios of the cow, to which they have given the name of amniotic acid.

PROPERTIES OF AMNIOTIC ACID.

Amniotic acid exists in the form of a white pulverulent powder. It is slightly acid, but sensibly reddens vegetable blues. It is difficultly soluble in cold, but readily soluble in boiling water, and in alcohol. When exposed to a strong heat it exhales an odour of ammonia and of prussic acid. Assisted by heat it decomposes carbonate of potash, soda, or ammonia. It produces no change in the solutions of silver, lead, or mercury, in nitric acid. Exposed to heat, it yields ammonia and prussic acid. It combines with alkalies, and forms soluble salts, which are decomposable by most of the acids.

Amniotic acid does not decompose the alkaline carbonates at the usual temperature, but it does so when assisted by heat. These properties are sufficient to shew that it is different from every other acid. It approaches nearest to the mucous acid and uric acid; but the first does not yield ammonia by heat, and the latter is not so soluble in hot water, does not crystallize in needles, and is insoluble in alcohol.

To obtain amniotic acid in a state of purity, evaporate the liquor of the amnios of the cow, to a syrupous consistence, which collects on the surface of the fluid.

Transfer the concentrated fluid into alcohol, digest it by heat, decant the alcohol, and repeat this operation for several times. Having done this, mingle the alcohol solution with one quarter of water, and abstract the alcohol by heat. Crystals of amniotic acid will be deposited upon cooling. In this case the acid is not pure. It is necessary to redissolve it in boiling water or alcohol, or re-crystallize it repeatedly.

Whether this acid exists in the liquor of the amnios of other animals is not yet known.

URIC ACID.

PART CXIV.

THIS acid exists in the urinary calculi, and also in human urine. That species of calculus which resembles wood in its colour and appearance consists almost entirely of uric acid. It was formerly called lithic acid, a name now superseded by the judicious remarks of Dr. Pearson, to whom we are indebted for a thorough knowledge of it.

PROPERTIES OF URIC ACID.*

Uric acid crystallizes in thin acicular and brilliant crystals, of a pale yellow colour. It has very little taste or odour. It is almost insoluble in cold, and sparingly soluble in 300 parts of boiling water; it then reddens delicate vegetable blues, but it becomes very soluble when combined with an excess of potash or soda. It is not acted upon by muriatic acid. Sulphuric acid, assisted by heat, decomposes it. It is soluble in nitric acid, and communicates to it a pink colour. The solution tinges animal matter of the same colour. It combines readily with alkalies and earths, and forms salts, which are decomposable by most of the other acids. Uric acid combined with soda is found crystallized in the human body, forming the gouty concretions of those afflicted with the gout. Uric acid is decomposable at high temperatures, and furnishes carbonate of ammonia, and carbonic acid, with very little oil or water. It is also decomposed by the nitric and oxygenized muriatic acids.

The acids called Formic and Zoonic are nothing more than acetic acid.

* For a more particular account of the uric acid and its connection with urinary calculus, and gouty concretions, see Thompson's Chemistry, vol. 5. and under this title. T. C.

GENERAL VIEW

OF

THE CHEMICAL PHENOMENA

OF

VEGETATION.

(SEE APPENDIX NO. 37.)

STRUCTURE OF PLANTS.

VEGETABLES are organized bodies, which are nourished by certain substances, received by and prepared within their vessels. They are all produced from seeds. They grow on the earth; at the bottom and on the surface of the ocean, and other waters; and *parasitical* upon other vegetables.

The structure of vegetables is nearly the same in all of them. They are composed of three principal parts, namely, the BARK, the WOOD, and the PITH. The *bark* is the outermost part: it covers the whole body of the plant or tree. On examining it minutely, *it* will be found to be also composed of three distinct substances, called the *epidermis*, the *parenchyma* and the *cortical layers*. The *epidermis* is a very thin transparent membrane which covers the whole outer part of the bark. The *parenchyma* is placed below it: it is a succulent green membrane, of a retiform texture. The *cortical layers* are the undermost: they consist of several thin membranes, composed of a multitude of longitudinal fibres, which cross each other, and form a kind of net-work. The *wood* lies under the bark; it constitutes by far the greatest part of the tree or vegetable. It consists of concentric layers, which are composed of longitudinal fibres. The *pith* is situated in the centre of the wood: it is a very spongy substance, and contains a vast number of cells. Through all these

different parts of the plant vessels are abundantly distributed, by means of which the functions necessary for the life and re-production of the vegetable are carried on. The conditions necessary for that purpose constitute the chemical phenomena of vegetation.

PHENOMENA OF VEGETATION.

If a seed, which consists of three principal parts namely, the *cotyledons*, the *radicle*, and the *plumula*, is placed in a situation favourable to its vegetation, it absorbs moisture, swells, and becomes soft. The *radicle* is converted into a root, and penetrates into the earth. The *cotyledons* emerge above the ground, and expand in the form of leaves (called the *seminal leaves*) and the *plumula* becomes the stem, to which the leaves are affixed. The whole seed, during this time, changes to a substance of a saccharine nature, which serves for the first food of the plant. When these appearances take place, the seed is said to *germinate* or *grow*. The food which was laid up in the seed for the embryo plant is then exhausted, and the plant derives its future nourishment principally from the air and soil.

FOOD OF PLANTS.*

The food of plants consists of water impregnated with vegetable and animal matter, and several gases; but water and air form the principal part of the food of every vegetable. They are decomposed in the vessels of the plant. The hydrogen of the water is retained; the oxygen is also absorbed, but the greatest part of it appears to be evolved again by the leaves. Water also serves to supply plants with carbonaceous matter, which it diffuses through the leaves, &c. and the same principle is absorbed from the air in the form of carbonic acid gas. These are the only resources whence the charcoal, contained in vegetables which grow in water and air, can be derived. The influence of heat and light are well known to be also very essential to the life of plants.

* The substances yielded by plants, when subjected to destructive analysis in close vessels, are ultimately resolveable into carbon, hydrogen, oxygen, azot, alkali. Water is always found in the state of water: there is no decisive proof that it is decomposed. Caloric and light are also necessary to vegetation. The food of plants must consist in those substances whereof all plants are composed. T. C.

The manner in which the functions of vegetables are carried on is hidden from our view; they appear to be analogous to the organization and nourishment of animals, and therefore belong to the sceince of physiology.

IMMEDIATE PRINCIPLES OF VEGETABLES.

The immediate parts of vegetables which are obtained by simple, easy, and frequently mechanical extractions, and which constitute every kind of vegetable matter, are MUCILAGE, or GUM; STARCH, or FECULA; JELLY; SUGAR; GLUTEN; FIXED OIL; VOLATILE OIL; CAMPHOR; WAX; RESIN; EXTRACT; CAOUTCHOUC; ACIDS; TAN; COLOURING MATTER; SUBER; and WOOD, or LIGNEOUS FIBRE.*

MUCILAGE or GUM. This substance is void of odour and taste. It is not fusible nor volatile. It is soluble in water, but not in alcohol or oils. It suffers no change on being exposed to air. Its solution in water is adhesive, and used as a paste. Nitric acid converts it into mucous acid. It is found in all young plants, and often exudes spontaneously from certain trees; the species of *mimosa* are the most productive, particularly the *nilotica*. Gum arabic, and wild cherry-tree and plum-tree gum, exhibit samples of this kind. Cruikshank obtained from gum, exposed to heat in a close vessel, mucous acid, carbonic acid, hydro-carbonate and ammonia; the residuum consisted of charcoal and lime. Its principles are consequently oxygen, hydrogen, carbon, nitrogen, and lime.

STARCH, or FECULA, constitutes the chief part of all the nutritive grains. Barley consists almost entirely of it. It appears in the form of a light, white, insipid, inodorous powder, soft to the touch. It is insoluble in cold, but easily soluble in boiling water, with which it forms a thick paste; which when dried assumes the appearance of a semi-transparent jelly, soluble again in hot water. Nitric acid converts it into oxalic and malic acid. It is inflammable. Starch may be extracted from

* The enumeration of vegetable principles by Thompson in his larger work, is much more full than the preceding; but all the chief and most important principles of vegetable analysis are here considered by Accum. T. C.

wheat, rye, potatoes, &c. by beating or kneading the flour of the substances with a large quantity of water. This fluid takes up the finest part of the starch, and deposits it again; the water is then decanted, and the starch is suffered to remain in the water till it becomes sour; it is then washed repeatedly, and dried. It is a ternary compound of carbon, hydrogen, and oxygen.

JELLY has a tremulous consistence. It is easily soluble in hot, but difficultly so in cold water; when strongly boiled for some time it loses the property of gelatinizing.* It has a pleasant taste, and is always coloured by the fruit from which it is obtained. When dried, it becomes transparent like glue. It is obtained by pressing out the juice of ripe fruits, allowing it to repose, and boiling it up and straining it through flannel. The juice of blackberries, currants, gooseberries, &c. combined with sugar and gelatinized, is well known.

SUGAR. Its properties are well known. It is very extensively diffused throughout vegetables; the juice of the sugar-cane affords it in abundance: it is likewise obtained from the sugar maple, from the beet-root, &c. The process for the preparation of sugar is, to press the juice, to boil it with lime-water, and with the serum of blood; to neutralize some oxalic acid, and separate from it many impurities; and then to evaporte it to a certain consistence, and cast it in a mould, or suffer it to crystallize. The constituent principles of sugar are, oxygen, carbon, and hydrogen.

GLUTEN, is an elastic, ductile, seemingly fibrous or membranous substance, insoluble in water, and putrefiable like animal matter. Its taste is insipid. It is slightly soluble in alcohol. It is dissolved by alkalies. Dried gently, it becomes semi-transparent, hard, and breaks with a noise and smooth fracture. It may be obtained by working or kneading flour repeatedly with water, the insoluble mass remaining is gluten. It may be obtained

* Hence the reason why in making jellies, if the quantity of sugar is not double that of the juice, it requires so long boiling to evaporate the superfluous water, that the jelly looses its gelatinizing property, or if it does gelatinize it soon spoils.

from the expressed juice of scurvy-grass, cresses, &c. by merely suffering it to stand exposed to the air, in order to separate the colouring matter, and then boiling it briskly for a few minutes. The gluten will coagulate, and may be separated by percolation. It consists of hydrogen, carbon, and nitrogen; and differs from the preceding vegetable principles by containing a much larger portion of nitrogen.

FIXED OIL is an immediate principle in many vegetables. It is somewhat thick, mild, inodorous, or slightly odorous. It is inflammable when very hot, or reduced into vapours. It absorbs oxygen from the air, and thickens or becomes concrete. It is insoluble in water, and forms soaps with alkalies. Fixed oils exist rarely except in nutritive seeds or kernels; it is extracted by mechanical pressure, or by trituration in water. Oil of olives, linseed, &c. belong to this class.

VOLATILE OIL is a fluid of a strong aromatic odour, and acrid taste. It is very inflammable, and not easily saponifiable by alkalies. It is volatilized at 212°. It is soluble in alcohol. It dissolves resin and camphor, and is easily inflammable by the affusion of nitrous acid. It is usually obtained by subjecting vegetables to distillation with water; part of it becomes dissolved by that fluid, but the greatest part floats on the surface. Oil of lavender, rosemary, &c. are volatile oils obtained in that manner.

CAMPHOR is a white, concrete, crystalline, brittle matter, of a strong pungent taste and odour; highly volatile and inflammable. It is soluble in alcohol, ether, and oils; water takes up a minute quantity. It is soluble in sulphureous, muriatic, or fluoric acid gas. The nitric acid also dissolves it, but the camphor soon separates, and floats upon its surface in the form of an oily-like fluid. It is principally extracted from the branches and wood of the *laurus camphora*, a species of laurel, growing in China, Japan, Sumatra, &c. by submitting them to distillation. The camphor thus obtained is afterwards purified in this and other countries, by re-subliming it. It exists in small quantities in thyme, rosemary, sage, and

many other labiated plants; it may be extracted by distilling these plants, and exposing their oil to the air at a temperature between 22° and 54°. The oil gradually evaporates, and the camphor is left behind in a crystalline state. It consists of hydrogen and charcoal.

WAX. The obvious qualities of wax are well known. It is insoluble in water and in alcohol; but soluble in volatile and fixed oils. Alkalies form with it a soap. It is very fusible, and inflammable at a high temperature. Wax is formed on the antheræ of flowers, whence it is collected by the bee. It is likewise found upon the upper surface of the leaves and fruits of many trees.

RESIN is either in the concrete or fluid state: it is soluble in alcohol, ether, or oils, but not in water. Heated strongly, it burns. It possesses a certain degree of transparency. Its colour is in general between yellow and brown. Resin frequently exudes spontaneously from plants, or flows out when they are wounded for that purpose. Sandarach, mastich, turpentine, &c. are resins.

EXTRACT exists abundantly in the juice of all plants: it is soluble in water, in alcohol, and in diluted acids; but insoluble in ether. It has a strong affinity for alumine. Exposed to air, it gradually absorbs oxygen, and then loses its solubility in water. The same effect is produced by oxygenated muriatic acid. It is obtained by mechanical pressure; by the simple infusion of the plant in a liquid; or by its decoction in water, and subsequent evaporation. Its component principles are carbon, hydrogen, nitrogen, and oxygen. Opium, liquorice juice, &c. are extracts.

CAOUTCHOUC, or ELASTIC GUM, is a concrescible juice, remarkable for the great elasticity which it acquires when dry. It can be stretched to a considerable extent without breaking, and immediately contracts again when the force is withdrawn. It is soluble in ether and volatile oils. When exposed to heat it melts, and burns with a bright flame. It is principally obtained by puncturing certain trees of South America, namely, the *hævea caoutchouc*, and the *jatropha elastica*. It is first thick and milky, and becomes concrete on being exposed to

the air. The blackish colour of the Indian rubber of commerce is owing to the method of drying it. It exists also in the missletoe, in gum mastich, and in various plants.

ACIDS. The acids which exist ready formed in vegetables are the citric, malic, oxalic, gallic, benzoic, tartareous, acetous, and suberic. They have been examined already under their respective heads.

TAN is obtained in the form of a dry powder. Its taste is very astringent. It is soluble in water and in alcohol: the solution, when concentrated, feels unctuous to the touch, and froths, when agitated, like a solution of soap. Its principal property is that of forming an insoluble compound with animal jelly. On this property is founded the art of tanning. Tan may be obtained, according to Proust, by mingling a decoction of galls with a solution of muriate of tin. An insoluble compound is formed, consisting of oxyd of tin and tan. This precipitate, after being washed, is to be dissolved in water, and a current of sulphurated hydrogen gas passed through it; this combines with the oxyd of tin, and the tan is left in the solution.

Until very lately tan had been known only as a production of nature; and the processes of chemistry had effected nothing more than its separation from the various substances with which it occurs combined. An important discovery however, has been very recently made by Mr. Hatchett, of the artificial formation of tan, from substances which unquestionably do not contain it, but only furnish its elements. The processes for its factitious production are very numerous; but they are arranged, by their author under three heads. 1st, The synthesis of tan may be effected by the action of nitric acid on animal or vegetable charcoal; 2dly, By distilling nitric acid from common resin, indigo, dragon's blood, and various other resinous substances; 3dly, By the action of sulphuric acid on common resin, elemi, assafœtida, camphor, &c. Of these various processes, we shall select the most simple, referring to Mr. Hatchett's very interesting paper for a fuller detail of the experiments. (See Phil. Trans. for 1805.)

To 100 grains of powdered charcoal, contained in a matrass, add an ounce of nitric acid (specific gravity 1.4) diluted with two ounces of water; place the vessel in a sand heat, and continue the digestion till the charcoal appears to be dissolved. A copious discharge of nitrous gas will take place. At the end of the second day, it may be necessary to add another ounce, and sometimes even a third, of nitric acid; and to continue the digestion during five or six days. A reddish-brown solution will be obtained, which must be evaporated to dryness in a glass vessel; taking care, in the latter part of the process, so to regulate the temperature, that the acid may be expelled, without decomposing the residuum. A brown glossy substance will be obtained, having a resinous fracture, and amounting in weight to 116 or 120 grains. This substance has the following properties:

1. It is speedily dissolved by cold water and by alcohol. 2. It has an astringent flavour. 3. Exposed to heat, it smokes but little, swells much, and affords a bulky coal. 4. Its solution in water reddens litmus paper. 5. The solution copiously precipitates metallic salts, especially muriate of tin, acetate of lead, and red sulphate of iron. These precipitates, for the most part, are brown, inclining to chocolate, excepting that of tin, which is blackish gray. 6. Gold is precipitated from its solution in a metallic state. 7. The earthy salts are precipitated by it. 8. Gelatine is instantly precipitated from water, in the state of a coagulum, insoluble both in cold and in boiling water.

The identity of this substance with tan can, therefore, be scarcely doubted, since the two bodies agree in having the same characteristic properties. The only essential circumstances of discrimination are, that the natural tan is destroyed, while the artificial is produced, by the agency of nitric acid; and that the artificial substance, even when formed, powerfully resists the decomposing action of this acid which readily destroys natural tan. Even, however, among the different varieties of the natural substance, Mr. Hatchett found essential differences in the facility of destruction by nitric acid. Those of oak bark and catechu are least destructible; and, in general, the varieties of tan seem to be least permanent, in proportion to the quantity of mucilage which they contain. In-

fusions of factitious tan differ, also, from those of the natural kind, in not becoming mouldy by keeping.

The artificial substance is a purer variety of tan than the natural one, inasmuch as it is perfectly free from gallic acid, and from extract; both of which are always present in the latter. The properties of the factitious compound vary a little, according to the mode of its preparation, principally in the colour of the precipitates, which they separate from metallic solutions. Those effected by tan, formed by processes of the first class, are always brown and by the second pale or deep yellow.

COLOURING MATTER exist in vegetables, combined with various other principles, and alters its properties according to the nature of the substances with which it is united. It has a strong affinity for alumine and oxyd of tin, in consequence of which their solutions precipitate infusions of colouring principle in water. Colouring matter is extracted from vegetable substances by water, alcohol, or oils; *viz.* from Brazil wood, logwood, alkanet root, &c.

On the extraction and fixation of colouring matter depends the formation of vegetable pigments or lakes, and the whole art of dying.

SUBER, or CORK, is a substance well known. It is the outer bark of the *quercus ruber*. It burns with a bright flame. Nitric acid converts it into a peculiar acid, called the suberic acid. Fourcroy supposes that the epidermis of all vegetables is a substance analogous to cork.

WOOD, or LIGNEOUS MATTER, forms the vegetable skeleton or the basis of wood. It consists of a multitude of longitudinal fibres. It is insipid, and insoluble in cold or hot water. It is somewhat transparent. It is combustible. When gradually heated, if air be excluded, it blackens, and becomes converted into charcoal, which retains exactly the form of the original mass. It may be exhibited pure, by boiling shavings of wood repeatedly in

water and alcohol, to extract from it all the substances soluble in these fluids.

SPONTANEOUS CHANGES OF VEGETABLE MATTERS.

Having considered those immediate principles of vegetables which constitute the body of the plant, and which are discoverable by simple processes; we shall now examine the spontaneous changes they undergo from the reaction of their parts upon each other under certain circumstances.

It is well known that all organized substances, when dead, suffer certain changes, if placed in a certain temperature, and in contact with air and water. Our present task, however, is to consider only such changes as should be examined by the chemical philosopher, on account of the light they throw upon many of the phenomena of nature and art; we shall therefore begin with the theory of fermentation, of which three kinds are distinguished, the vinous, acetous, and putrefactive, characterized principally from each other by the nature of their products.

1. VINOUS FERMENTATION.

Before we consider this species of fermentation we must premise, that by the term fermentation in general is understood a spontaneous motion which is excited in vegetable or other organized substances, and which totally changes their properties. The conditions necessary for that purpose are, a certain degree of fluidity, a certain degree of heat, and access of air.

All vegetable substances, containing saccharine matter, are susceptible of the vinous fermentation. When any sweet vegetable juice or other saccharine matter is suffered to be exposed undisturbed to a temperature between 60° and 80° F. it first becomes turbid and viscid; an intestine motion and increase of bulk gradually takes place; air bubbles are discharged from its whole mass, bursting forth with a perceivable noise, and forming a kind of froth or

yeast; the sweetness of the fluid disappears, and a pungent taste is acquired. After a certain time these phenomena cease, the fluid deposits a copious sediment, and becomes again clear, bright, and transparent. It has then acquired a brisk taste, a vinous odour, and an intoxicating power.

WINE.

Wine is the product of fermentation, obtained under similar circumstances from the expressed juice of the grape. The grapes are put into a vessel, exposed to a temperature of about 50° F. bruised and much agitated; after which the fermentation is excited, and the appearances before mentioned take place. When the fermentation ceases, the wine is drawn off from the lees into casks, where it undergoes a second, though insensible, fermentation, which more intimately developes its principles; and and it is this change which causes the difference between *old* and *new wine.* Wine is more spirituous and intoxicating as the quantity of saccharine matter contained in the juice of the grape is greater. By processes similar to this, raisin, gooseberry, and other wines, cyder and perry, may be obtained.

BEER.

Porter is made in this country from barley, in the following manner; barley is first reduced to malt, by being steeped in water; it is then drawn off, and the barley is spread upon a floor about 6 inches thick, where it begins to germinate. The germination is suffered to continue till the radicle is $\frac{3}{4}$ or $\frac{1}{4}$ of the length of the grain. As soon as this is accomplished, the grain is spread thinner, and turned over twice a day, for several days; it is then transferred to the kiln heated with *wood,* and dried highly, or till it acquires a brown colour; it is then called *brown malt.** From this malt, porter is brewed in the following manner:

* Malt very gently dried by means of *coke* for making ale, is called *pale malt.*

A quantity of malt freed from its germ is coarsely ground and put into a vessel, called the mash-tub. Hot water, under the degree of boiling (of about 160° or 180° F.) is poured on it, and the whole is stirred intimately together, either by machinery or by the hand of man; by this means the soluble part of the malt is extracted. When this operation is over, the liquor called the *extract* is drawn off. Another infusion is then made by means of water of a higher temperature, which infusion of course is weaker than the former, and these are either mixed or kept separate. Both have a sweet taste; they contain the saccharine, the extractive, the amilaceous, and the gelatinous parts of the grain. The infusion thus obtained is called *wort*. It is then boiled with hops to give it a certain aromatic bitterness, and to render it less liable to be spoiled in keeping; and is cooled as expeditiously as possible in very large shallow vessels called *coolers*, in which it measures no more than from one to two inches. As soon as it is cold it is transferred into the *fermenting-tub*, a certain quantity of yeast is added, and the whole is suffered to ferment. When the fermentation has advanced to a due degree, and the yeast ceases to rise, the beer is divided into smaller casks, to facilitate the separation of the yeast: and, lastly, it is conveyed into barrels, and kept in cool places, with the precaution of supplying the loss it suffers by evaporation. Eight bushels of malt, and 10lb. of hops, produce upon an average 100 gallons of London porter.

ALCOHOL, OR ARDENT SPIRIT.

If wine or beer be distilled, a colourless fluid passes over into the receiver of a strong heating taste, a penetrating odour, and an intoxicating property. This fluid is called ardent spirit. It is capable of being inflamed without a wick, and burns without smoke, and with a flame which is blue at the edges, and white in the middle. It is very volatile, and consequently evaporates spontaneously at common temperatures. It is miscible with water and alkalies. It dissolves resins, sugar, essential oils, camphor, &c. It is decomposed by most of the dense acids: the result is a very odorous, pungent, inflammable, and highly volatile fluid, called *ether*.

To prepare *sulphuric ether*, any quantity of sulphuric acid is gradually mingled with an equal weight of alcohol in a retort; heat is then applied by a sand-bath, the retort being connected with a receiver kept cool by water; a colourless fluid condenses in the receiver. When the distilled liquor amounts to about half the quantity of alcohol employed, or when the neck of the retort becomes obscured with white fumes, the distillation is to be stopped; a thick black fluid remains in the retort. The distilled liquor, which is the ether, impure from the admixture of water and sulphureous acid, is to be mixed with a small quantity of potash, and subjected to distillation by a very gentle heat. It is thus obtained nearly pure.

RATIONALE....The theory of the formation of ether is far from being accurately ascertained. According to the explanation which, till lately, was generally received, in the formation of sulphuric ether, the alcohol is decomposed by part of its hydrogen attracting part of its oxygen of the sulphuric acid: the balance of attractions existing between the principles of the alcohol being thus broken, a large quantity of carbon is precipitated, and the remaining elements of the alcohol combine, and form the ether.

Nitric ether may be obtained in the following manner: Two parts of alcohol are poured into a strong glass bottle, provided with a ground stopper, and placed in a frigorific mixture, or in snow mingled with ice broken small, and in this situation the alcohol is suffered to cool some degrees below the freezing point. One part and a half of nitrous acid are then successively affused, yet by drops only, and at sufficiently long intervals, for fear of the mixture being heated, which, as likewise every agitation, ought to be most cautiously avoided. When the mixture is completed, the glass is for some time left standing quiet in the cold, and well stopped. The ether is, after this, found swimming on the surface, from which it is carefully taken off by means of a separatory funnel, and cautiously rectified over a little potash or lime.

RATIONALE....The theory of the formation of nitric ether is not less obscure than that of the production of sulphuric ether. It has been ascertained by the experi-

ments of Bayen, that the acid is either decomposed, or combined in such a manner that it is not discoverable, by an alkali: he found that the mixture of the acid and the alcohol, after being digested for some time, required only the ninth part of the quantity of potash for its saturation, which the quantity of acid employed would have done. The alcohol is also partially decomposed, as oxalic and acetous acids are formed. No carbon, however, is precipitated in a sensible form. It may be said, perhaps, that in this process, part of the carbon, hydrogen, and oxygen of the alcohol enter into new combinations, forming the acetous and oxalic acids; and that the remaining quantities of these elements combine with part of the acid to form the nitric ether.

Acetic and phosphoric ether may be obtained by distilling equal parts of the most concentrated acids of these kinds with alcohol, and proceeding as directed before. No good method of obtaining *muriatic ether* is hitherto known; the methods directed do not furnish a fluid which possesses all the properties of ether.

2. ACETOUS FERMENTATION.

If wine or any other vinous fluid be exposed to a heat, from 75° to 85° F. and air be admitted, the properties of the fluid are altered remarkably, it loses its taste and odour, it becomes sour, and turns into vinegar. During this change the fluid is rendered turbid, its surface becomes covered with a mouldy pellicle, a quantity of fibrous matter separates, and forms a kind of skin, which sinks to the bottom, vulgarly called *mother of vinegar.*

VINEGAR.

The most usual method of making vinegar is by means of two vessels, each containing some refuse of grapes, or such matters; one of these is filled with wine, the other is half filled. In this latter the fermentation first begins, at which time it must be checked by filling this vessel out of the other. Soon after, the fermentation takes place in the second vessel, which is to be refilled in turn; and so the process goes on alternately for some weeks, until the vinegar is made.

Vinegar may also be prepared from water, containing about three pounds of raisins or sugar to the gallon: or from the faces or dregs of apples, pears, &c. from which the juice has been expressed.

Vinegar fully fermented is clear and nearly colourless; it has a pleasant pungent odour, and a sour taste. It possesses all the properties of an acid. When freed from its mucilage, and other heterogeneous admixtures, by distillation, it constitutes acetous acid.*

PUTREFACTIVE FERMENTATION.

When the spontaneous decomposition of vegetable substances is suffered to proceed beyond the production of the acetous acid, the vinegar gradually becomes viscid and foul; air is emitted with a fetid odour; an earthy sediment is deposited; and when the whole process is finished scarcely any thing remains but the salts, the alcohol, and the earths which formed the constituent parts of the vegetable: the fluid, if any is left, is water and acetous acid. This decomposition is putrefactive fermentation: its properties are more striking in animal matter.

* In the course of acetous fermentation in grain, the process appears to be this: Fecula or Starch, is gradually converted into Saccharine matter; this into alcohol, which by combining with the oxygen of the atmosphere becomes acetous acid or vinegar. T. C.

GENERAL EXAMINATION

OF

ANIMAL SUBSTANCES.

(SEE APPENDIX NO. 38.)

ANIMAL substances are far more complicated in their composition than vegetable. Their principal base is hydrogen, combined with a large portion of nitrogen, charcoal, oxygen, phosphorus, and not unfrequently sulphur.

The different substances which constitute the body of animals are the following:

BONES of animals contain much phosphate of lime and carbonate of lime, deposited in a gelatinous net-work. They are soluble in all the dense acids which reduce the gelatinous net-work to the naked state; it may then be dissolved by boiling water. Mr. Hatchett has found that the bones of quadrupeds and fishes contain also sulphate of lime.

MUSCLES are the principal fleshy parts connected with the bones. They are chiefly composed of fibrin, albumen, gelatine, extract, phosphate of soda, phosphate of ammonia, phosphate of lime, and carbonate of lime.

MEMBRANES are thin, semi-transparent, soft, and pliable bodies, which wrap up or form the external covering of the muscles, bones, viscera, and other parts of the body. Mr. Hatchett has proved that they are destitute of phosphate of lime and saline matters, and that they are principally composed of coagulated albumen.

LIGAMENTS are those strong fibrous and elastic substances which connect the bones with each other: they have been little examined; they yield a quantity of gelatine, by boiling, but by far the greatest part remains unaltered.

TENDONS, commonly called *sinews*, are strong pearl-coloured bodies which connect the muscles with the bones. By long and strong ebullition they are dissolved into a nutritious gelatinous mass.

THE SKIN envelopes the whole surface of animals. It is composed of three parts, namely, the *epidermis*, or *cuticle*, the *mucous membrane*, and the *cutis*, or true skin. The epidermis is an elastic membrane; it is that part of the skin which is raised in blisters. It is principally composed of albumen, gelatine, and phosphate of lime. The mucous membrane, which is situated immediately under the epidermis, is composed of a soft gelatinous substance which gives to the skin its peculiar colour. The true skin or cutis, is a thick, firm, elastic membrane, composed of a number of fibres interwoven with each other. Both this and the former are composed of gelatine, fibrin, albumen, and phosphate of lime.

FAT, TALLOW, and MARROW, are of an oleaginous nature, greatly resembling vegetable expressed oil. They may be considered as highly oxygenated oil, containing sebacic acid and phosphate of lime.

NAILS of animals, Mr. Hatchett has shown, are chiefly composed of a membranous substance, resembling coagulated albumen.

HORNS and HOOFS of animals greatly resemble the former in all their properties.

HAIR, according to Bertholet, yielded carbonate of ammonia, charcoal, nitrogen, and sulphur.

FEATHERS yield nearly the same products as hair. Mr. Hatchett has proved that the quill is chiefly composed of coagulated albumen.

SHELLS, or the crustaceous coverings of certain animals, such as echini, lobsters, crabs, cray-fish, &c. and also the shells of eggs, greatly resemble bones in their composition, but the proportion of the carbonate of lime they contain far exceeds that of the phosphate. Mother of pearl is composed, according to Hatchett, of carbonate of lime and membrane. Fish scales are composed of membrane and phosphate of lime.

BLOOD is concrescible by repose and cold, and coagulable by heat. It separates into two different parts by rest. The cause of this spontaneous separation is unknown. The white part is called the *serum*, the other coloured part is denominated the *crassamentum*, or *clot*. The serum consists of albumen, gelatine, carbonate, muriate, and phosphate of soda, phosphate of lime, and sulphur. The crassamentum contains albumen, soda, and subphosphate of iron. When blood, the moment it is drawn from an animal, is strongly agitated with a stick or other substance, a white, solid, elastic matter separates, called *fibrin*, or animal gluten. It contains more nitrogen than any of the former parts of the blood.

MILK separates spontaneously into three parts, namely, *cream*, *curd*, and *whey*. The first is a butyraceous oil, the second a caseous albumen, and the third a saccharine lymph. Milk is a compound of water, oil, albumen, gelatine, sugar of milk, muriate of soda, sulphur, phosphate of lime, and muriate of potash.

SALIVA, which is secreted by the glands in the mouth, consists of mucilage, albumen, muriate of soda, phosphate of soda, phosphate of lime, and phosphate of ammonia.

TEARS consist, according to Vauquelin, of water, mucilage, soda, muriate of soda, phosphate of lime, and phosphate of soda.

MUCUS OF THE NOSE is analogous to the latter acid. It contains more coagulable mucilage. Its great viscidity is owing to the absorption of oxygen, on being longer exposed to the air than tears.

BILE is a fluid secreted by the liver from the venous blood. It is composed of water, resinous matter, albumen, soda, phosphate of soda, phosphate of lime, muriate of soda, saccharine salt, iron, and sulphurated hydrogen.

BILIARY CALCULI, or GALL-STONES, are concrete bodies deposited in the gall-bladder, and biliary duct. They are inflammable, very fusible by heat, partly soluble in alkalies, alcohol, or oils. They contain a bitter resinous matter, benzoic acid, lime, soda, and ammoniacal salts. They vary remarkably in their external properties and chemical composition.

URINE of healthy persons always contains phosphoric acid, phosphate of lime, phosphate of magnesia, carbonic acid, carbonate of lime, uric acid, benzoic acid, gelatine, albumen, urea (or a substance in which the colour and odour of urine principally resides) resin, muriate of soda, phosphate of soda, phosphate of ammonia, muriate of ammonia, and sulphur.

URINARY CALCULI are frequently composed of uric acid, united to ammonia; others consist of phosphoric acid, combined with ammonia and magnesia.

WAX OF THE EAR is composed, according to Vauquelin, of albumen, soda, phosphate of lime, a colouring matter, and a bitter oil.

TRACHEAL HUMOURS, or MUCOUS, which lubricates the trachea and the bronchia; the ocular humours, the humours of the alimentary canal, and other cavities of the body, have not been examined with attention. Fourcroy has ascertained that the fæces are always acid, and strongly redden vegetable blue.

SINOVIA, or the peculiar viscid semi-transparent fluid, found within the capsular ligaments of the different joints of animals, Marqueron and Hatchett found to be composed of fibrous matter, albumen, soda, muriate of soda, phosphate of lime, and water.

SEMINAL FLUID consists of water, mucilage, phosphate of lime and soda. The semen of other animals has not been analysed.

LIQUOR OF THE AMNIOS, which surrounds the fœtus in the uterus in every part, contains, in women, water, muriate and carbonate of soda, phosphate of lime, and albumen. In the cow, an extractive animal matter, sulphate of soda, and a peculiar crystallizable acid, called *amniotic acid.*

CEREBRAL PULP has been examined by Fourcroy. The pulpy matter of which it chiefly consists approaches most nearly in properties to albumen, which is mixed with a saline fluid, consisting of phosphate of lime, soda, and ammonia.

PERSPIRABLE MATTER has not yet been accurately analysed. It seems to be principally water holding in solution a small quantity of lymph and carbonic acid.

HUMOUR OF THE PROSTATA has not been examined. It appears to be albuminous, and of the same nature as all the white humours.

CHYLE, AND THE PANCREATIC AND GASTRIC JUICES, have not yet been analysed with accuracy.

INTESTINAL GAS is composed ordinarily of many gases; principally of carbonic acid, nitrogen, carbonated and sulphurated hydrogen. The first is the ordinary product of a good digestion; the last are the sign and result of a troubled, slow, or irregular digestion.

SPONTANEOUS DECOMPOSITION OF ANIMAL MATTER.

The spontaneous decomposition which animal matter suffers is called *putrefaction.* The conditions necessary are, a certain degree of moisture, a certain temperature, and a free access of air. The phenomena which attend putrefaction are the following: the colour of the sub-

stance first becomes paler, and its texture soft; it acquires an intolerable fetid odour, and its organization is destroyed. The substance increases in bulk, air bubbles are disengaged, and the whole becomes gradually converted into a greenish black matter of a pulpy consistence; and lastly fluid: a phosphorescent light is frequently observable. In this state it remains for some time, sending forth a horrible offensive odour. This odour gradually disappears, the soft substance acquires more and more consistence, and becomes at last converted into a dry friable powder, resembling a mixture of earths.

It is obvious, that during this process all the principles, which form the organized animal matter, act upon each other according to certain laws; the precise nature of which has not been hitherto accurately ascertained. The gases which are developed, and which fill the cavities and cellular texture, so as to inflate and puff up the body, are evidently ammonia, formed by the union of the nitrogen and hydrogen of the animal matter; and afterwards phosphorated hydrogen, sulphurated hydrogen, carbonated hydrogen, and carbonic acid. In some cases nitric acid is formed. The earthy-like residue, which remains after the process of putrefaction has taken place, consists of charcoal, with other earthy, oily, and saline matters. Thus it appears that the elements, which formed the organized animal body, unite together, during the process of putrefaction, two and two, and form new sets of binary compounds of a more simple nature, which again enter with other substances, under favourable circumstances, into combinations, and thus serve for the reproduction and support of dead and living matter.

ANALYSIS

OF

MINERAL WATERS.

THE complete and accurate analysis of mineral waters is one of the most difficult subjects of chemical manipulation, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Long and attentive study of the science is therefore essential to qualify any one for undertaking exact and minute determinations of the proportion of the component parts of bodies. Such minuteness, however, is scarcely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of them. We shall not attempt, therefore, to lay down rules for accurate analysis, but shall only describe such experiments as are suited to afford an insight into the kind, but not to decide the exact proportion of the constituent principles of natural waters.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The nature of the strata, in the neighbourhood of the spring, will often furnish useful suggestions respecting the contents of the water; the period of the year should be stated at which the analysis was performed; and whether after a rainy or dry season. The temperature of the water must be carefully observed, as it issues from the spring; and

the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water may be found by weighing a bottle, which is capable of containing a known weight of distilled water, at a certain temperature, filled with the water, under examination, at the same temperature. It is proper, also, to examine, on the spot, the channel through which the water has flowed; to collect any deposit that may have been formed; and to investigate its nature.

The effects of heat on the water may be next tried. Many waters lose their transparency when their temperature is raised, and let fall a considerable deposit. The quality of this may, in some degree, be conjectured from its appearance. If its colour be brownish-yellow, it consists, either wholly or chiefly, of oxyd of iron; if white, or nearly white, it is composed principally of the earthy carbonates. A mineral water, containing iron, deposits that metal also, when exposed to the atmosphere; and a thin pellicle forms on its surface, whether stagnant in a natural reservoir, or collected in a separate vessel. By this exposure, iron may be sometimes discovered in a water, though not easily detected at first; because it becomes further oxydized, and more sensible to the action of tests. Sulphuretted hydrogenous waters exhibit a sediment, even when preserved in a well-closed vial; the hydrogen quitting the sulphur, which settles in the form of a white powder.

EXAMINATION OF MINERAL WATERS BY RE-AGENTS.

Water is never presented by nature in a state of complete purity. Even when collected as it descends in the form of rain, chemical tests detect in it a minute proportion of foreign ingredients. And when it has been absorbed by the earth, has traversed its different strata, and is returned to us by springs, it is found to have acquired various impregnations. The readiest method of judging of the contents of natural waters is by applying what are

termed tests, or, re-agents; *i. e.* substances which, on being added to a water, exhibit quickly, by the phenomena they produce, the nature of the saline, or other ingredients. For example, if, on adding infusion of litmus to any water, its colour is changed to red, we infer, that the water contains an uncombined acid: if this change ensues, even after the water has been boiled, we judge that the acid is a fixed, and not a volatile one: and if, on adding muriate of barytes, a precipitate falls down, we safely conclude that the peculiar acid, present in the water, is either entirely or in part the sulphuric acid. We shall first enumerate the tests generally employed in examining waters, and describe their application, and, afterwards, indicate by what particular tests the substances, generally found in waters, may be detected.

In many instances, however, a mineral water may contain a saline or other ingredient, but in such small quantity as to escape discovery by tests. It is therefore advisable to apply the tests of fixed substances to the water, after reducing its bulk one-half, or more, by evaporation, as well as in its natural state.

The use of tests, or re-agents, has been employed by Mr. Kirwan to ascertain, by a careful examination of the precipitate, not only the *kind*, but the *quantity*, of the ingredients of mineral waters. This will be best understood from an example. It is an established fact, that 100 parts of crystallized muriate of soda, when completely decomposed by nitrate of silver, yield, as nearly as possible, 235 of precipitate. From the weight of the precipitate, separated by nitrate of silver from a given quantity of any water, it is therefore easy, when no other muriatic salt is present, to infer what quantity of muriate of soda was contained in the water; since every hundred grains of muriated silver indicate, pretty accurately, 42½ of crystallized common salt. The same mode of estimation may be applied in various other instances; and the rule for each individual case is given by Mr. Kirwan, in part ii. chap. 2. of his "Essay on the Analysis of Mineral Waters." In most instances, also, it will be found stated in the following description of the use of the various re-agents.

I. *Infusion of Litmus, Syrup of Violets, &c.*

The infusion of litmus is prepared by steeping this substance, first bruised in a mortar, and tied up in a piece of muslin, in distilled water, which extracts its blue colour.

If the colour of the infusion tends too much to purple, it may be amended by a drop or two of solution of ammonia; but of this no more must be added than is barely sufficient, lest the delicacy of the test should be impaired.

The syrup of violets is not easily obtained pure. The genuine syrup may be distinguished from the spurious by a solution of corrosive sublimate (or muriate of mercury) which changes the former to green, while it reddens the latter. When it can be procured genuine, it is an excellent test of acids, and may be employed in the same manner as the infusion of litmus.

Paper stained with the juice of the March violet, or with that of the scrapings of radishes, or red cabbage, answers a similar purpose. In staining paper for the purposes of a test, it must be used unsized; or, if sized, it must previously be well washed with warm water; because the alum, which enters into the composition of the size, will otherwise change the vegetable colour to red.

In the Philosophical Magazine, vol. i. p. 180, may be found some recipes for other test liquors, invented by Mr. Watt.

Infusion of litmus is a test of most uncombined acids.

1. If the infusion redden the unboiled, but not the boiled water, under examination; or if the red colour, occasioned by adding the infusion to a recent water, return to blue, on boiling; we may infer, that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

2. To ascertain whether the change be produced by carbonic acid or by sulphuretted hydrogen, when experiment shows that the reddening cause is volatile, add a little lime-water, or, in preference, barytic water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little

muriatic acid. Sulphuretted hydrogen may also be contained, along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described.

3. Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying. The mineral and fixed acids redden it permanently. That these acids, however, may produce their effect, it is necessary that they should be present in a sufficient proportion. (See Kirwan on Mineral Waters, p. 40.) The dark-blue paper, which is generally wrapped round loaves of refined sugar, is not discoloured by carbonic acid or sulphuretted hydrogen, but only by the stronger acids.

II. *Infusion of Litmus reddened by acetous Acid—Spirituous Tincture of Brazil-wood—Tincture of Turmeric, and Paper stained with each of these three Substances—Syrup of Violets—Tincture of Red Cabbage.*

All these different tests have one and the same object.

1. Infusion of litmus reddened by vinegar, or litmus paper, reddened by vinegar, has its blue colour restored by alkalies and earths, and by carbonated alkalies and carbonated earths.

2. Turmeric paper and tincture are changed to a reddish-brown by alkalies, whether freed from carbonic acid or not, by earths, freed from carbonic acid, but not by carbonated earths.

3. The red infusion of brazil-wood, and paper stained with it, become blue by alkalies and earths, and even by the latter, when dissolved by an excess of carbonic acid. In the last-mentioned case, however, the change will either cease to appear, or will be much less remarkable, when the water has been boiled.

4. Syrup of violets, when pure, is, by the same causes, turned green; as is also paper stained with the juice of the violet, or with the scrapings of radishes, or tincture of red-cabbage.

III. *Tincture of Galls.*

Tincture of galls is the test generally employed for discovering iron; with all the combinations of which it pro-

duces a black tinge, more or less intense according to the quantity of iron. The iron, however, in order to be detected by this test, must be in the state of a red oxyd, or, if oxydized in a less degree, its effects will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation, or boiling, we may know whether the iron be held in solution by carbonic acid, or by a fixed acid. For,

1. If it produce its effect before the application of heat, and not afterward, carbonic acid is the solvent.

2. If after, as well as before, a fixed and vulgarly called mineral acid is the solvent.

3. If, by the boiling, a yellowish powder be precipitated, and yet galls continue to strike the water black, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid. A neat mode of applying the gall-test was used by M. Klaproth, in his analysis of the Carlsbad water; a slice of the gall-nut was suspended by a silken thread in a large bottle of the recent water, and so small was the quantity of iron, that it could only be discovered in water fresh from the spring, by a slowly-formed and dark cloud, surrounding the re-agent. (Klaproth, vol. i. p. 279.)

IV. *Sulphuric Acid.*

1. Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alkalies or earths.

2. If lime be present, the addition of sulphuric acid occasions, after a few days, a white precipitate.

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric and muriatic salts, in a dry state, or dissolved in very little water, on adding sulphuric acid, and applying heat, are decomposed; and if a stopper, moistened with solution of ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

V. *Nitric and Nitrous Acids.*

These acids, if they occasion effervescence, give the same indications as the sulphuric. The nitrous acid has been recommended as a test distinguishing between hepatic waters that contain hydro-sulphuret of potash, and those that contain only sulphuretted hydrogen gas. In the former case, a precipitate ensues on adding nitrous acid, and a very fetid smell arises; in the latter, a slight cloudiness only appears, and the smell of the water becomes less disagreeable.

VI. *Oxalic Acid and Oxalates.*

This acid is a most delicate test of lime, which it separates from all its combinations.

1. If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs, by means of a quill or glass tube, we may infer that lime (or barytes, which has never yet been found pure in waters) is present in an uncombined state.

2. If the oxalic acid occasion a precipitate before, but not after boiling, the lime is dissolved by an excess of carbonic acid:

3. If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present; because some acids decompose the oxalic, and others dissolving the oxalate of lime, prevent it from appearing. (Vid. Kirwan on Waters, page 88.)

The oxalate of ammonia or of potash (which may easily be formed by saturating their respective carbonates with a solution of oxalic acid) are not liable to the above objection, and are preferable, as re-agents, to the uncombined acid. Yet even these oxalates fail to detect lime when supersaturated with muriatic or nitric acids; and, if such an excess be present, it must be saturated, before adding the test, with ammonia. A precipitation will then be produced.

The quantity of lime, contained in the precipitate, may be known, by first calcining it with access of air, which

converts the oxalate into a carbonate; and by expelling, from this last, its carbonic acid, by a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit.

The fluate of ammonia recommended by Scheele, is a most delicate test of lime. It may be prepared by adding carbonate of ammonia to diluted fluoric acid, in a leaden vessel, observing that there be a small excess of acid.

VII. *Alkalies, and carbonated alkalies.*

1. The alkalies precipitate all earths and metals, whether dissolved by volatile or fixed menstrua, but only in certain states of dilution; for example, sulphate of alumine may be present in water, in the proportion of 4 grains to 500, without being discovered by potash or soda. As the alkalies precipitate so many substances, it is evident that they cannot afford any very precise information, when employed as re-agents. From the colour of the precipitate, as it approaches to a pure white, or recedes from it, an experienced eye will judge, that the precipitated earth contains less or more of metallic admixture; and its precise composition must be ascertained by rules which will presently be given.

2. Alkalies also decompose all salts with basis of ammonia, which becomes evident by its smell (except the salts are dissolved in much water) and also by the white fumes it exhibits when a stopper, moistened with muriatic acid, is brought near.

3. Carbonates of potash and of soda have similar effects.

4. Ammonia precipitates all earthy and metallic salts. Besides this property, it also imparts a deep blue colour to any liquid that contains copper or nickel in solution.

5. Carbonate of ammonia has the same properties, except that it does not precipitate magnesia from its combinations. Hence, to ascertain whether this earth be present in any solution, add the carbonate of ammonia till no farther precipitation ensues; filter the liquor; raise it nearly to 212° Fahrenheit; and then add ammonia. If any precipitation now occurs, we may infer the presence of magnesia. It must be acknowledged

that zircon, yttria, and glucine, would escape discovery by this process; but they have never yet been found in mineral waters; and their presence can scarcely be expected.

VIII. *Lime-Water.*

1. Lime-water is applied to the purposes of a test, chiefly for detecting carbonic acid. Let any liquor supposed to contain this acid be mixed with an equal bulk of fresh prepared lime-water. If carbonic acid be present, either free or combined, a precipitate will immediately appear, which, on adding a few drops of muriatic acid, will again be dissolved with effervescence.

2. Lime-water will also show the presence of corrosive sublimate by a brick-dust coloured sediment. If arsenious acid (common arsenic) be contained in a liquid, lime-water, when added, will occasion a precipitate, consisting of lime and arsenious acid, which is very difficultly soluble in water. This precipitate, when mixed up with oil, and laid on ignited coals, yields the well-known garlic smell of arsenic.

IX. *Barytes, and its Solution in Water.*

1. A solution of barytes is even more effectual than lime-water in detecting the presence of carbonic acid, and is much more portable and convenient; since, from the crystals of this earth, the barytic solution may at any time be immediately prepared. In discovering carbonic acid, the solution of barytes is used similarly to lime-water, and if this acid be present, gives, in like manner, a precipitate soluble with effervescence in dilute muriatic acid.

2. The barytic solution is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate not soluble in muriatic acid. Strontia has similar virtues as a test. The quantity of the precipitated substance, indicated by the weight of the precipitate, will be stated in No. XV.

X. *Metals.*

1. Of the metals, silver, bismuth, and mercury are tests of the presence of hydro-sulphurets, and of sulphuretted hydrogen gas. If a little quicksilver be put into a bottle containing water impregnated with either of these substances, its surface soon acquires a black film, and, on shaking the bottle, a blackish powder separates from it. Silver and bismuth are speedily tarnished by the same cause.

2. The metals may be used also as tests of each other, on the principle of elective affinity. Thus, for example, a polished iron cylinder, immersed in a solution of sulphate of copper, soon acquires a coat of this metal; and the same in other similar examples.

XI. *Green Sulphate of Iron.*

This is the only one of the sulphates, except that of silver, applicable to the purposes of a test. When used with this view, it is generally employed for ascertaining the presence of oxygen gas, of which a natural water may contain a small quantity.

A water, suspected to contain this gas, may be mixed with a little recently dissolved green sulphate of iron, and kept corked up, in a vial completely filled by the mixture. If an oxyd of iron be precipitated in the course of a few days, the water may be inferred to contain oxygen gas. This substance may also be detected by applying tincture of litmus, or tincture of red cabbage, in the following manner: Tinge the water blue with tincture of litmus, or red cabbage, fill a cylinder or vial with it, invert the cylinder into a basin of water, and introduce into it nitrous gas, till about $\frac{1}{15}$ of the vessel be filled. If the water contains oxygen, a portion of the nitrous gas will combine with it, and become converted into nitric acid, the consequence of which will be, that the blue-coloured water will assume a red tinge. Even the portion of oxygen gas in the water, may be estimated by the quantity of ammonia necessary to restore the original colour. If the water retains its blue tinge, we may be certain that it contains no sensible portion of oxygen.

XII. *Sulphate, Nitrate, and Acetate of Silver.*

These solutions are all, in some measure, applicable to the same purpose.

1. They are peculiarly adapted to the discovery of muriatic acid and of muriates. For the silver, quitting its solvent, combines with the muriatic acid, and forms a flaky precipitate, which, at first, is white, but, on exposure to the sun's light, acquires a bluish, and finally a black colour; it is soluble in liquid ammonia. This precipitate Dr. Black states to contain, in 1000 parts as much muriatic acid as would form 425$\frac{1}{2}$ of crystallized muriate of soda, which estimate scarcely differs at all from that of Klaproth. The same quantity of muriate of silver (1000 parts) indicates, according to Kirwan, 454$\frac{3}{4}$ of muriate of potash. A precipitation, however, may arise from other causes, which it may be proper to state.

2. The solution of silver in acids is precipitated by carbonated alkalies and earths. The agency of the alkalies and earths may be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved.

3. The nitrate and acetate of silver are decomposed by the sulphuric and sulphureous acids; but this may be prevented by adding, previously, a few drops of nitrate or acetite of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted, and the solution of silver added. Should a precipitate now take place, the presence of muriatic acid, or some of its combinations, may be suspected. To obviate uncertainty, whether a precipitate be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when no uncombined alkali or earth is present, is affected only by the latter acid.

4. The solutions of silver are also precipitated by sulphuretted hydrogen, and by hydro-sulphurets; but the precipitate is then reddish, or brown or black; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble, in great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

5. The solutions of silver are precipitated by extractive matter; but in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

XIII. *Nitrate and Acetate of Lead.*

1. Acetate of lead, the most eligible of these two tests, is precipitated by sulphuric and muriatic acids; but, as of both these we have much better re-agents, we do not enlarge on its application to this purpose.

2. The acetate is also a test of sulphuretted hydrogen and of hydro-sulphurets of alkalies, which occasion a black precipitate; and if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hydrogen gas, they are soon rendered visible, especially when the water is a little warmed.

3. The acetate of lead is employed in the discovery of uncombined boracic acid, a very rare ingredient of waters. To ascertain whether this be present, some cautions are necessary. (a) The uncombined alkalies and earths (if any be suspected) must be saturated with acetic or acetous acid. (b) The sulphates must be decomposed by acetate or nitrate of barytes, and the muriates by acetate or nitrate of silver. The filtered liquor, if boracic acid be contained in it, will continue to give a precipitate, which is soluble in nitric acid of the specific gravity of 1.3.

XIV. *Nitrate of Mercury, prepared with, and without Heat.*

This solution, differently prepared, is sometimes employed as a test. But, since other tests answer the same purposes more effectually, it is unnecessary to describe the application of mercurial solutions. For the same reason, also, oxygenized muriate of mercury is of little use in discovering the ingredients of mineral waters.

XV. *Muriate, Nitrate, and Acetate of Barytes.*

1. These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate, insoluble in dilute muriatic acid.

They are decomposed, however, by carbonated alkalies; but the precipitate occasioned by carbonates is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding previously a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. I. p. 168.) about $45\frac{1}{2}$ of sulphuric acid of the specific gravity 1850; according to Clayfield, (Nicholson's Journal, 4to, iii. 38.) 33 of acid, of specific gravity 2240; according to Thenard, after calcination, about 25; and according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried sulphate of soda; while 136.36 of the same substance indicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

From Klaproth's experiments, it appears, that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallized salt. The same chemist has shown, that 100 grains of sulphate of barytes are produced by the precipitation of 71 grains of sulphate of lime.

2. Phosphoric salts occasion a precipitate also, which is soluble in muriatic acid without effervescence.

XVI. *Prussiates of Potash and of Lime.*

Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily assume a blue colour on the addition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron, with the solutions of which in acids it produces a Prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alkalies or earths, which, if present, prevent the detection of very minute quantities of iron.

1. If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate of potash,

the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

2. Should the precipitation ensue in the boiled water, the solvent is a fixed acid, the nature of which must be ascertained by other tests.

In using the prussiate of potash for the discovery of iron, considerable caution is necessary, in order to attain accurate results. The prussiate should, on all occasions, be previously crystallized; and the quantity of oxyd of iron, essential to its constitution, or at least an invariable accompaniment, should be previously ascertained in the following manner. Expose a known weight of the crystallized salt to a low red-heat in a silver crucible. After fusing and boiling up, it will become dry, and will then blacken. Let it cool; wash off the soluble part: collect the rest on a filter; dry it, and again calcine it with a little wax. Let it be again weighed, and the result will shew the proportion of oxyd of iron present in the salt which has been examined. This varies from 22 to 30 and upwards per cent. When the test is employed for discovering iron, let a known weight of the salt be dissolved in a given quantity of water; add the solution gradually; and observe how much is expended in effecting the precipitation. Before collecting the precipitate, warm the liquid, which generally throws down a further portion of Prussian blue. Let the whole be washed and dried, and then calcined with wax. From the weight of the oxyd obtained, deduct that quantity, which, by the former experiment, is known to be present in the prussiate that has been added; and the remainder will denote the quantity of oxyd of iron present in the liquor which is under examination.

3. Besides iron, the prussiated alkalies also precipitate muriate of alumine. No conclusion, therefore, can be deduced respecting the non-existence of muriate of alumine, from any process in which the prussic test has previously been used. It will, therefore, be proper, if a salt of alumine be indicated by other tests, to examine the precipitate effected by prussiate of potash. This may be done by repeatedly boiling it to dryness with muriatic acid, which takes up the alumine, and leaves the prussiate of iron. From the muriatic solution, the alumine may be precipitated by a solution of carbonate of potash.

4. According to Klaproth, (II. 55.) solutions of Yttria (which earth, however, is not likely to be present in any mineral water) afforded with the Prussian test a white precipitate, passing to pearl gray, which consists of prussiate of yttria. This precipitate disappears on adding an acid, and hence may be separated from prussiate of iron. The same accurate chemist states, that the Prussian test has no action on salts with base of glucine (ib.) but that it precipitates zircon from its solutions. (II. 14.)

The prussiated alkalies decompose, also, all metallic solutions, excepting those of gold, platina, iridium, rhodium, osmium, and antimony.

XVII. *Succinate of Soda and of Ammonia.*

1. The succinate of soda was first recommended by Gehlen, and afterwards employed by Klaproth (Contributions, II. 48.) for the discovery and separation of iron. The salt with base of ammonia has also been used for a similar purpose by Dr. Marcet, physician to Guy's Hospital, in a skilful analysis of the Brighton chalybeate water, which is published in the new edition of Dr. Saunders's Treatise on Mineral Waters.

The succinic test is prepared by saturating carbonate of soda or ammonia with succinic acid. In applying the test, it is necessary not to use more than is sufficient for the purpose; because an excess of it re-dissolves the precipitate. The best mode of proceeding is to heat the solution containing iron, and to add gradually the solution of succinate, until it ceases to produce any effect. A brownish precipitate is obtained, consisting of succinate of iron. This, when heated with a little wax, in a low red heat, gives an oxyd of iron, containing about 70 per cent. of the metal. From Doctor Marcet's experiments, it appears, that 100 grains of iron, dissolved in sulphuric acid, then precipitated by the succinic test, and afterwards burned with wax, gives 148 of oxyd of iron; that is, 100 grains of the oxyd indicate about 67½ of metallic iron.

2. The succinates, however, it is stated by Dr. Marcet and Mr. Ekeberg, precipitate alumine, provided there be no considerable excess of acid in the aluminous salt. On magnesia it has no action, and hence may be successfully

employed in the separation of these two earths. If 100 parts of octahedral crystals of alum be entirely decomposed by succinate of ammonia, they give precisely 12 parts of alumine after having been exposed to a dull red heat. The succinate of ammonia, it is stated by Mr. Ekeberg (*Journ. des Mines*, No. 70.) precipitates glucine; and the same test, according to Klaproth, throws down zircon from its solutions.

XVIII. *Phosphate of Soda.*

An easy and valuable method of precipitating magnesia has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses; first to dissolve the carbonate of magnesia, formed when it is added to the solution of magnesian salt, and afterwards to yield the earth to phosphoric acid, with which and ammonia it forms a triple salt. For this purpose, a solution of carbonate of ammonia, prepared with a portion of that salt which has been exposed, spread on a paper, for a few hours, to the air, is to be added to the solution of the magnesian salt sufficiently concentrated; or to a water suspected to contain magnesia, after being very much reduced by evaporation. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of magnesia, or about 64 of muriate of magnesia.

XIX. *Muriate of Lime.*

Muriate of lime is principally of use in discovering the presence of alkaline carbonates, which though they very rarely occur, have sometimes been found in mineral waters. Carbonate of potash is said to exist in the waters of Aix-la-Chapelle; that of soda, in the waters of a few springs and lakes; and the ammoniacal carbonate was detected by Mr. Cavendish in the waters of Rathbone-place. Of all the three carbonates, muriate of lime is a sufficient re-agent; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid.

With respect to the discrimination of the different alka-

lies, potash may be detected by the nitro-muriate of platina, which distinctly and immediately precipitates that alkali and its compounds, and is not affected by soda. Carbonate of ammonia may be discovered by its smell; and by its precipitating a neutral salt of alumine, while it has no action apparently on magnesian salts.

To estimate the proportion of an alkaline carbonate present in any water, saturate with sulphuric acid, and note the weight of real acid which is required. Now 100 grains of real sulphuric acid saturate 121.48 potash, and 78.32 soda.

XX. *Solution of Soap in Alcohol.*

This solution may be employed to ascertain what is vulgarly called the comparative *hardness* of waters. With distilled water it may be mixed without any change ensuing; but, if added to a hard water, it produces a milkiness, more considerable as the water is less pure; and, from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is owing to the alkali quitting the oil, whenever there is present in a water any substance, for which the alkali has a stronger affinity than it has for oil. Thus all uncombined acids, and all earthy and metallic salts, decompose soap, and occasion that property in waters which is termed hardness.

XXI. *Alcohol.*

Alcohol, highly freed from water, when mixed with any water, in the proportion of about an equal bulk or upwards, precipitates all the salts which it is incapable of dissolving. (See Kirwan on Waters, p. 263.)

XXII. *Hydro-sulphuret of Ammonia.*

This and other hydro-sulphurets, as well as water saturated with sulphuretted hydrogen, may be employed in detecting lead and arsenic; with the former of which they give a black, and with the latter a yellowish, precipitate.

TABLE,

Shewing the Substances that may be expected in Mineral Waters, and the means of detecting them.

Acids in general. Infusion of litmus.—Syrup of violets, I.

Acid, boracic. Acetate of lead, XIII. 3.

Acid, carbonic. Infusion of litmus, I. 1. 2.—Lime-water, VIII. 1.—Barytic water, IX. 1.

Acid, muriatic. Nitrate and acetate of silver, XII.

Acid, nitric. Sulphuric acid, IV. 4.

Acid, phosphoric. Solutions of barytes, XV. 2.

Acid, sulphureous. By its smell; and destroying the colour of litmus, and of infusion of red roses:—by the cessation of the smell a few hours after the addition of the black oxyd of manganese.

Acid, sulphuric. Solution of barytes, IX. Barytic salts, XV. Acetate of lead, XII.

Alkalies in general. Vegetable colours, II. Muriate of lime, XIX.

Ammonia. By its smell, and tests, II.

Barytes, and its compounds. By sulphuric acid, IV.

Carbonates in general. Effervescence on adding acids.

Earths dissolved by carbonic acid. By a precipitation on boiling;—by alkalies, freed from carbonic acid, VII.

Iron dissolved by carbonic acid. Tincture of galls, III. 1. Prussiate of potash, XVI. 1. Succinate of ammonia, XVII.

Iron dissolved by sulphuric acid. The same tests, III. 3. XVI. 2. XVII.

Lime. Water saturated with carbonic acid. Blowing air from the lungs. Oxalic acid, VI.

Lime dissolved by carbonic acid. Precipitation on boiling.—Alkalies, VII. Oxalic acid, VI.

Lime dissolved by sulphuric acid. Oxalate of ammonia, VI. Barytic solutions, X. and XV.

Magnesia dissolved by carbonic acid. Precipitation on boiling,—the precipitate soluble in dilute sulphuric acid.

Magnesia dissolved by other acids. Precipitated by ammonia, not by the carbonate, VII. 5. Phosphate of soda, XVII.

Muriates of alkalies. Solutions of silver, XII.

Muriates of lime. Solutions of silver, XII. Oxalic acid, and oxalate of ammonia, VI.

Sulphates in general. Barytic solutions, IX. and XV. —Acetate of lead, XII.

Sulphate of alumine. Barytic solutions, IX. and XV. —A precipitate by carbonate of ammonia not soluble in acetous acid, but soluble in alkalies by boiling. Succinates, XVII. 2.

Sulphate of lime. Barytic solutions, IX. and XV.— Oxalic acid, and oxalates, VI.—A precipitate by alkalies not soluble in dilute sulphuric acid.

Sulphurets of alkalies. Polished metals, X. Odour on adding sulphuric or muriatic acid.—Nitrous acid, V.

Sulphuretted hydrogen gas. By its odour. Infusion of litmus, I. Polished metals, X. Acetate of lead, XIII. 2.*

Analysis of Waters by Evaporation.

The reader, who may wish for rules for the complete and accurate analysis of mineral waters, will find in almost every elementary work a chapter allotted to this subject. He may also consult Bergman's Physical and Chemical Essays, Vol. I. Essay 2. and Kirwan's Essay on the Analysis of Mineral Waters, London, 1799. As this work, however, may sometimes be employed as a travelling companion, and may attend the chemist where other works cannot be had, it may be proper to state, briefly, the mode of analysing waters by the more certain, but still not unobjectionable, mode of evaporation.

Before evaporation, however, the gazeous products of the water must be collected, which may be done by filling with it a large glass bottle, capable of holding about 50 cubical inches, and furnished with a ground stopper and bent tube. The bottle is to be placed, up to its neck, in a tin kettle filled with brine, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what is lost by evaporation. The disengaged gas is conveyed, by a bent tube, into a graduated jar, filled with, and inverted in, mercury, where

* The vapour of putrefying animal or vegetable matter dissolved in water, according to Klaproth, vol. I. p. 590, often gives a deceptive indictation of sulphuretted hydrogen.

its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar, till the water has obtained its maximum of temperature. This must be suffered to escape, and its quantity to be deducted from that of the water submitted to experiment.

In determining, with precision, the quantity of gas, it is necessary to attend to the state of the barometer and thermometer. If a considerable proportion of gas be contained in a mineral water, the most commodious method of receiving it is into a gazometer.

The gases most commonly found in mineral waters, are *carbonic acid; sulphuretted hydrogen; nitrogen; oxygen gas;* in the neighbourhood of volcanoes only, *sulphureous acid gas.*

To determine the proportion of the gases, constituting any mixture obtained from a mineral water in the foregoing manner, the following experiments may be made. If the use of re-agents has not detected the presence of sulphuretted hydrogen, and there is reason to believe, from the same evidence, that carbonic acid forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver. Pass up a small portion of solution of potash, and agitate this in contact with the gas. The amount of the diminution will show how much carbonic acid has been absorded; and, if the quantity submitted to experiment was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxygen and azotic gases; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer.

If sulphuretted hydrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass-vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hydrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hydrogen by oxy-muriatic acid gas (obtained from muriatic acid and hyper oxy-muriate of potash) adding

the latter gas very cautiously, as long as it produces any condensation. Or, perhaps, a better plan of effecting the separation is the following, recommended by Mr. Henry: Half-fill a graduated vial with the mixed carbonic acid and sulphuretted hydrogen gases, and expel the rest of the water by oxy-muriatic acid gas. Let the mouth of the bottle be then closed with a well-ground stopper, and let the mixture be kept twenty-four hours. Then withdraw the stopper under water, a quantity of which fluid will immediately rush in. Allow the bottle to stand half an hour without agitation. The redundant oxy-muriatic acid gas will thus be absorbed; and very little of the carbonic acid will disappear. Supposing that, to 10 cubic inches of the mixed gases, 10 inches of oxy-muriatic gas have been added, and that, after absorption, by standing over water, 5 inches remain: the result of this experiment shows, that the mixture consisted of equal parts of sulphuretted hydrogen and carbonic acid gases.

Whenever this complicated admixture of gases occurs, as in the case of Harrowgate-water, it is advisable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphuretted hydrogen; and that of azote and oxygen by the other. In the latter instance, remove both the absorbable gases by caustic potash; and examine the remainder in the manner already directed.

Nitrogen gas sometimes occurs in mineral waters, almost in an unmixed state. When this happens, the gas will be known by the characters already described as belonging to it. Sulphureous acid gas may be detected by its peculiar smell of burning brimstone, and by its discharging the colour of an infusion of roses, which has been reddened by the smallest quantity of any mineral acid adequate to the effect.

The vessels employed for EVAPORATION should be of such materials as are not likely to be acted on by the contents of the water. I prefer those of unglazed biscuit ware; but, as their surface is not perfectly smooth, and the dry mass may adhere so strongly as not to be easily scraped off, the water, when, reduced to about one-tenth or less, may be transferred, with any deposit that may have taken place, into a smaller vessel of glass. Here let it be evaporated to dryness.

(*a*) The dry mass, when collected and accurately weighed, is to be put into a bottle, and highly rectified alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol, and dry and weigh the remainder.

(*b*) To the undissolved residue, add eight times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

(*c*) Boil the residuum, for a quarter of an hour, in sometimes more than 500 times its weight of water, and afterwards filter.

(*d*) The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

1. The solution in alcohol (*a*) may contain one or all of the following salts: muriates of lime, magnesia, or barytes, or nitrates of the same earths. Sometimes, also, the alcohol may take up a sulphate of iron, in which the metal is highly oxydized, as will appear from its reddish-brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add above half its weight of strong sulphuric acid; and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes; the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis of the salts, let the heat be continued till no more fumes arise, and let it then be raised to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates may be separately decomposed, by boiling with three or four times their weight of carbonate of potash. The carbonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid, and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up. Lime and magnesia may

also be separated by the use of the phosphate of soda, applied in the manner already described in the preceding Section.

The presence of barytes, which is very rarely to be expected, may be known by a precipitation ensuing on adding sulphuric acid to a portion of the alcoholic solution, which has been diluted with 50 or 60 times its bulk of pure water.

II. The watery solution (*b*) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallization. For this purpose let one half be evaporated by a very gentle heat, not exceeding 80° or 90°. Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda, or common salt. The remaining solution, on cooling very gradually, will, perhaps, afford crystals distinguishable by their form and other qualities. When various salts, however, are contained in the same solution, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must, therefore, be examined by tests, or re-agents.

The presence of an uncombined alkali, as well as uncombined acids, will be discovered by the stained papers, and tests already pointed out. The vegetable alkali, or potash, may be distinguished from the mineral, or soda, by saturation with sulphuric acid, and evaporation to dryness, the sulphate of soda being much more soluble than that of potash; or, by super-saturation, with the tartareous acid, which gives a soluble salt with soda, but not with potash. Muriate of platina, also, is an excellent test of potash and its combinations; for with the smallest portion of this alkali, or any of its salts, it forms a distinct and immediate precipitate; while it is not at all affected by the mineral alkali or its compounds.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and of the basis. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III. The solution by boiling water contains scarcely any thing besides sulphate of lime.

IV. The residuum (*d*) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly oxydized iron. Evaporate the solution to dryness. If it contain acetate of lime only, a substance will be obtained which does not attract moisture from the air; if magnesia be present, the mass will deliquate. To separate the lime from the magnesia, proceed as in I.

The residue, insoluble in acetous acid, may contain alumine, iron, and silex. The two first may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterwards by a fixed alkali.

For a more complete analysis of mineral waters, the reader is referred to Kirwan's excellent Essay on the Analysis of Mineral Waters; and for the modes of analysing ores of metals, earths, stones, inflammable fossils, saline compounds, and mineral substances in general, to the author's Practical Essay on the Analysis of Minerals.

ANALYSIS OF SOILS.

THE following rules, for determining the composition of a soil, are copied from a Memoir, presented by Mr. Davy to the Board of Agriculture.

1. *Utility of Investigations relating to the Analysis of Soils.*

The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science: many useful facts and observations, with regard to it, have been furnished by Mr. Young; it has been examined by lord Dundonald, in his Treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan, in his excellent Essay on Manures; but the inquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honour of laying before the board an account of those methods of analysing soils which appear most precise and simple, and most likely to be useful to the practical farmer; they are founded partly upon the labours of the gentlemen whose names have been just mentioned, and partly upon some latter improvements.

2. *Of the Substances found in Soils.*

The substances which are found in soils are certain mixtures or combinations of some of the primitive earths, animal or vegetable matter in a decomposing state, cer-

tain saline compounds, and the oxyd of iron. These bodies always retain water, and exist in very different proportions in different lands; and the end of analytical experiments is the detection of their quantities and mode of union.

The *earths* found in common soils are principally silex. or the earth of flints, alumine, or the pure matter of clay, lime, or calcareous earth, and magnesia.

Silex, or the earth of flints, when perfectly pure, appears in the form of a white powder, which is incombustible, infusible, insoluble in water, and not acted upon by common acids; it is the substance which constitutes the principal part of rock crystal: it composes a considerable part of hard gravelly soils, of hard sandy soils, and of hard stony lands.

Alumine, or pure clay, in its perfect state is white, like silex; it adheres strongly to the tongue, is incombustible, insoluble in water, but soluble in acids, and in fixed alkaline menstrua. It abounds most in clayey soils and clayey loams; but even in the smallest particles of these soils it is usually united to silex and oxyd of iron.

Lime is the substance well known in its pure state under the name of quicklime. It always exists in soils in combination, and that principally with fixed air or carbonic acid, when it is called carbonate of lime; a substance which in the most compact form constitutes marble, and in its looser form, chalk. Lime, when combined with sulphuric acid (oil of vitriol) produces sulphate of lime (gypsum) and with phosphoric acid, phosphate of lime. The carbonate of lime, mixed with other substances, composes chalky soils and marles, and it is found in soft sandy soils.

Magnesia, when pure, appears as white, and in a lighter powder than any of the other earths; it is soluble in acid, but not in alkaline menstrua; it is rarely found in soils; when it does exist, it is either in combination with carbonic acid, or with silex and alumine.

Animal decomposing matter exists in very different states, according as the substances from which it is produced are different; it contains much carbonaceous substance; and may be principally resolved by heat into this substance, volatile alkali, inflammable aeriform products, and

carbonic acid: it is principally found in lands that have been lately manured.

Vegetable decomposing matter is likewise very various in kind; it contains usually more carbonaceous substance than animal matter, and differs from it in the results of its decomposition, principally in its not producing volatile alkali; it forms a great proportion of all peats; it abounds in rich mould, and is found in larger or smaller quantities in all lands.

The *saline compounds* found in soils are very few, and in quantities so small, that they are rarely to be discovered. They are principally muriate of soda (common salt) sulphate of magnesia (Epsom salt,) and muriate and sulphate of potash, nitrate of lime, and the mild alkalies.

The *oxyd of iron* is the same with the rust produced by exposing iron to the air and water; it is found in all soils, but is most abundant in yellow and red clays, and in yellow and red siliceous sands.

A more minute account of these different substances would be incompatible with the object of this paper. A full description of their properties and agencies may be found in the elementary books on chemistry.

3. *Instruments required for the Analysis of Soils.*

The really important instruments required for the analysis of soils are few, and but little expensive. They are, a balance capable of containing a quarter of a pound of common soil, and capable of turning when loaded with a grain; a series of weights from a quarter of a pound Troy to a grain; a wire sieve, sufficiently coarse to admit a pepper corn through its apertures; an Argand lamp and stand; some glass bottles; Hessian crucibles; porcelain, or queen's ware evaporating basins; a Wedgewood pestle and mortar; some filters made of half a sheet of blotting paper, folded so as to contain a pint of liquid, and greased at the edges; a bone or ivory knife, and an apparatus for collecting and measuring aeriform fluids.

The chemical substances, or re-agents required for separating the constituent parts of the soil, are muriatic acid, sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash, solution of soap,

solution of carbonate of ammonia, of muriate of ammonia, solution of neutral carbonate of potash, and nitrate of ammonia.

4. *Mode of collecting Soils for Analysis.*

In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens that upon plains the whole of the upper stratum of the land is of the same kind, and in this case one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains;

these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote to a certain extent their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; aluminous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on; and calcareous soils are soft, and much less adhesive than aluminous soils.

5. *Mode of ascertaining the Quantity of Water of Absorption in Soils.*

Soils, though as dry as they can be made by continued exposure to the air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a basin of porcelain, to a temperature equal to 300* Fahrenheit; and in case a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish: as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted; and when in four hundred grains of soil it reaches

* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and the siliceous earth as most abundant.

6. *Of the Separation of Stones, Gravel, and vegetable Fibres, from Soils.*

None of the loose stones, gravel, or large vegetable fibres, should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and in consequence influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

7. *Separation of the Sand and Clay, or Loam, from each other.*

The great number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marle, and vegetable and animal matter. This may be effected in a way sufficiently accurate, by agitation of the soil in water. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the minutely divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally

separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and their respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline matter, and the soluble animal and vegetable matters, if any exist in the soil.

8. *Examination of the Sand.*

By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or ever necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part: it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole indicates the proportion of calcareous sand.

9. *Examination of the finely divided Matter of soils, and mode of detecting mild Lime and Magnesia.*

The finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy

matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and an half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxyd of iron, but very seldom any alumine.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solutions, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of common prussiate of potash must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxyd of iron, and the solution of the prussiate must be dropped in till no further effect is produced. To ascertain its quantity it must be collected in the same manner as other solid precipitates, and heated red; the result is oxyd of iron.

Into the fluid, freed from oxyd of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alcaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid; and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumine should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with caustic potash, sufficient to cover the solid matter. This substance dissolves alumine, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity

of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* about 45 per cent; so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is unknown, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid, and one part of the matter of the soil, must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases: the difference between their weight before and after the experiment denotes the quantity of carbonic acid lost; for every four grains and a half of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper. The estimation is, for every ounce measure of carbonic acid, two grains of carbonate of lime.

10. *Mode of ascertaining the Quantity of insoluble finely divided Animal and Vegetable Matter.*

After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time of ignition almost always denotes a considerable

proportion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposable substances may be assisted by the agency of nitrate of ammoniac, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and is itself at the same time decomposed and lost.

11. *Mode of separating Aluminous and Siliceous Matter and Oxyd of Iron.*

The substances remaining after the decomposition of the vegetable and animal matter are generally minute particles of earthy matter, containing usually alumine and silex with combined oxyd of iron.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance remaining after the action of the acid may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumine and the oxyd of iron, if any exist, are both dissolved by the sulphuric acid: they may be separated by carbonate of ammoniac, added to excess: it throws down the alumine, and leaves the oxyd of iron in solution, and this substance may be separated from the liquid by boiling.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid: this, however, is scarcely ever the case; but the process for detecting them and ascertaining their quantities is the same in both instances.

The method of analysis by sulphuric acid is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent, and the residuum of the incineration

must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver, or of well-baked porcelian. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxyd of iron and all the earths, except silex, will be dissolved in combination as muriates. The silex, after the usual proeess of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

12. *Mode of discovering Soluble Animal and Vegetable Matter, and Saline Matter.*

If any saline matter, or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour, and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous or gelatinous substance; if it be white and transparent, it may be considered as principally saline matter. Nitrate of potash (nitre) or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magnesia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammoniac, but precipitate solution of muriate of barytes.

13. *Mode of detecting Sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*

Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance

four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process of gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

It would not fall within the limits assigned to this paper to detail any processes for the detection of substances, which may be accidentally mixed with the matters of soils. Manganese is now and then found in them, and compounds of the barytic earth; but these bodies appear to bear little relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

14. *Statement of Results and Products.*

When the examination of a soil is completed, the products should be classed, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate, or sulphate, of lime are discovered by the independent process XIII, a correction must be made for the independent process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

		Grains.
Of water of absorption		18
Of loose stones and gravel, principally siliceous		42
Of undecompounded vegetable fibres		10
Of fine siliceous sand		200
Of minutely divided matter separated by filtration, and consisting of		
Carbonate of lime	25	
Carbonate of magnesia	4	
Matter destructible by heat, principally vegetable	10	
Silex	40	
Alumine	33	
Oxyd of iron	4	
Soluble matter, principally sulphate of potash and vegetable extract	5	
Gypsum	3	
Phosphate of lime	2	
	——	125
Amount of all the products		395
Loss		5

In this instance the loss is supposed small; but, in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty four hundred grains, there is no reason to suspect any want of due precision in the processes.

15. *This general Method of Analysis may, in many cases be much simplified.*

When the experimenter is become acquainted with the use of the different instruments, the properties of the reagents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid, IX, may be omitted. In examining

peat soils, he will principally have to attend to the operation by fire and air, X, and in the analysis of chalks and loams, he will be often able to omit the experiment by sulphuric acid, XI.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with : but, in overcoming them, the most useful kind of practical knowledge will be obtained ; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information ; but perhaps there is no better mode of gaining it than that of attemping original investigations. In persuing his experiments, he will be continually obliged to learn from books the history of the substances he is employing or acting upon ; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

16. *On the Improvement of Soils, as connected with the Principle of their Composition.*

In cases when a barren soil is examined with a view to its improvement, it ought in all cases, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation : the difference given by their analysis would indicate the methods of cultivation ; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance ; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marle, or chalk to lands, there are no particular chemical principles to be observed ; but when quick lime is used, great care must be taken that it is not obtained from the magnesian limestone ; for in this case, as has been shown by Mr. Tennant, it is exceedingly injurious to land.* The mag-

* Phil. Trans. for 1799, p. 505 This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

nesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analyzed by the process of carbonate of lime and magnesia, IX.

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or the agency of lately made quicklime. And the defect of animal and vegetable matter must be supplied by animal or vegetable manure.

17. *Sterile Soils in different Climates and Situations must differ in Composition.*

The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils to absorb moisture, a principle essential to their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in vallies.* The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may occasionally be prevented from being barren, in a moist climate, by the influence of a substratum of sand or gravel.

18. *Of the Chemical Composition of fertile Corn Soils in this Climate.*

Those soils that are most productive of corn contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

* Kirwan, Trans. Irish Academy, Vol. v. p. 175.

The quantity of calcareous earth is, however, very various, and, in some cases, exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one-ninth of sand, chiefly siliceous, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere*

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighths of the parings of lime-stone, was very proper for wheat.

19. *Of the Composition of Soils proper for bulbous Roots and for Trees.*

In general, bulbous roots require a soil much more sandy, and less absorbent than the grasses. A very good potatoe soil, from Varfal, in Cornwall, afforded me seven-eighths of siliceous sand; and its absorbent power was so small, that one hundred parts lost only two by drying at 400° Fahrenheit.

* This soil was sent to me by T. Pool, esq. of Nether Stowey. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils, which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter; and one hundred parts of the entire soil, submitted to analysis, produced,

Water	3	parts
Silex	54	
Alumine	28	
Carbonate of lime	3	
Oxyd of iron	5	
Decomposing vegetable matter	4	
Loss	3	

20. *Advantages of Improvements made by changing the Composition of earthy Parts of Soils.*

From the great difference of the causes that influence the productiveness of lands, it is obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops; but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expence.

Description of the Apparatus for the Analysis of Soils.

Fig. 17, Plate I.; *a*, *b*, *c*, *d*, *e*, *f*. The different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils, *a* represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *f*, the graduated measure; *f*, *e*, the bottle for containing the bladder *d*. When this instrument is used, a given quantity of soil is introduced into *a*, *b* is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced into the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e*, *f*, which is filled with water. The graduated measure is placed under the spout of *f e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder, and displaces a quantity of water in *e f* equal to it in bulk, and this water flows through the tube or spout into the graduated measure; the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which, two grains of carbonate of lime may be estimated.

WEIGHTS AND MEASURES.

Comparison of English with French Weights and Measures.

"To employ, as the fundamental unity of all measures' "a type taken from nature itself, a type as unchangeable as "the globe on which we dwell; to propose a metrical "system, of which all the parts are intimately connected "together, and of which the multiples and subdivisions "follow a natural progression, which is simple, easy to "comprehend: this is most assuredly a beautiful, great, "and sublime idea, worthy of the enlightened age in which "we live."

Such were the ideas which influenced the French National Institute, when they chose as the base of the whole metrical system the fourth part of the terrestrial meridian between the equator and the north pole. They adopted the ten millionth part of this arc for the unity of measure, which they denominated *metre*, and applied it equally to superficial and solid measures, taking for the unity of the former the square of the decuple, and for that of the latter the cube of the tenth part of the metre. They chose for the unity of weight the quantity of distilled water which the same cube contains when reduced to a constant state presented by nature itself; and, lastly, they decided that the multiples and sub-multiples of each kind of measure, whether of weight, capacity, surface, or length, should be always taken in the decimal progression, as being the most simple, the most natural, and the most easy for calculation, according to the system of numeration which all Europe has employed for centuries.

By a careful measurement of the arc between Dunkirk and Mountjoy, they found the length of the metre to be equal to 443.296 lines of the toise of Peru. The cube decimetre of distilled water, taken at its maximum of density and weight *in vacuo*, that is the unity of weight, was found to be 18827.15 grains of the pile of Charlemagne. By actual comparison, the metre was found to be equal to 39.371 English inches at 62°, the temperature universally employed in the comparison of English standards: and upon these data the following tables have been constructed.

TABLE I.

Tables of Weights and Measures.

Troy Weight.

Pound.		Ounces.		Drachms.		Scruples.		Grains.		Grammes.
1	=	12	=	96	=	288	=	5760	=	372.96
		1	=	8	=	24	=	480	=	31.08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.06475

Avoirdupois Weight.

Pound.		Ounces.		Drachms.		Grains.		Grammes.
1	=	16	=	256	=	7000	=	453.25
		1	=	16	=	437.5	=	28.32
				1	=	27.975	=	1.81

Measures.

Gallon.		Pints.		Ounces.		Drachms.		Cub. Inch.		Litres.
1	=	8	=	128	=	1024	=	231	=	3.78515
		1	=	16	=	128	=	38.875	=	0.47898
				1	=	8	=	1.8047	=	0.02957
						1	=	0.2256	=	0.00369

Measures of Length; the Metre being at 32°, and the Foot at 62°.

		English Inches.		Mil.	Fur.	Yds.	Feet.	Inch.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Chiliometre	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6

Measures of Capacity.

		Cubic Inches.		*English.*			
				Tons.	Hogs.	Wine Gall.	Hints.
Millilitre	=	.06103					
Centilitre	=	.61028					
Decilitre	=	6.10280					
Litre	=	61.02800	=	0	0	0.	2.1133
Decalitre	=	610.28000	=	0	0	2.	5.1352
Hecatolitre	=	6102.80000	=	0	0	26.419	
Chiliolitre	=	61028.00000	=	0	1	12.19	
Myriolitre	=	610280.00000	=	10	1	58.9	

Measures of Weight.

		English Troy Grains.		*Avoirdupois.*		
				Poun.	Oun.	Drams.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
Gramme	=	15.4440				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Chiliogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

TABLE II.

Shewing the Specific Gravities of different Bodies at a Medium Temperature.

Distilled water, - -	1.0	
Gases.		
Oxygen. - - -	0.0013562	L.
——— - - -	0.00133929	B.
Hydrogen, - -	0.0001	K.
——— - -	0.00009911	B.
——— - -	0.000094671	L.
Sulphuretted hydrogen,	0.00135	K.
Carburetted hydrogen,	0.000804.	C.
———	0.000787	C.
Light do - -	0.000063	C.
——— - -	0.000554	C.
Nitrogen, - -	0.0012	K.
——— - -	0.00119048	B.
——— - -	0.001189	L.
Atmospheric air, - -	0.0012308	L.
——— - -	0.00123609	B.
Nitrous oxyd, - -	0.00197	D.
Nitric oxyd, - -	0.001343	D.
——— - -	0.00130179	B.
——— - -	0.0014631	K.
Carbonic oxyd, - -	0.001167	C.
———acid, - -	0.00186161	B.
——— - -	0.0018454	L.
Sulphurous acid, - -	0.00253929	B.
——— - -	0.0018856	K.
Muriatic acid, - -	0.00213482	B.
Ammonia, - -	0.00065357	B.
——— - -	0.00073539	K.

Oxygenized muriatic acid gas, and fluoric acid gas unknown.

L. Lavoisier. B. Brisson. K. Kirwan. C. Cruikshank. D. Davy.

SOLIDS.

Diamond,	3.5212	Hogs lard,	0.9478
Native sulphur,	2.0332	Yellow wax,	0.9648
Melted do.	1.9907	White do.	0.9686
Phosphorus,	1.7140	Spermaceti,	0.9433
Platina fused,	19.5000	Rosin,	0.0727
Gold do.	19.2581	Sandarac,	1.0920
Mercury,	13.5681	Mastich,	1.0742
Lead,	11.3523	Copal,	1.0452
Silver,	10.4743	Elemi,	1.0682
Bismuth,	9.8227	Labdanum,	1.1862
Cobalt,	7.8227	Resin of Guaiac,	1.2289
Copper,	7.7880	Resin of jalap,	1.2185
Nickel,	7.3806	Dragons blood,	1.2045
Tin,	7.2914	Tacamahaca,	1.0463
Cast iron,	7.2070	Benzoin,	1.0924
Zinc,	7.1908	Storax,	1.1098
Manganese,	6.8500	Gum ammoniac,	1.2071
Antimony,	6.7021	Gamboge,	1.2216
Tungsten,	6.6785	Olibanum,	1.1732
Tellurium,	6.1150	Myrrh,	1.3600
Molybdena,	6. nearly.	Scammony,	1.2354
Arsenic,	5.7633	Galbanum,	1.2120
Uranium, titanium, chrome, & columbium, unknown.		Assa fœtida,	2.3275
		Hepatic aloes,	1.3586
Potash,	4.6215	Socotrine aloes,	1.3795
Barytes,	4.	Opium,	1.3366
Magnesia,	2.3298	Gum arabic,	1.4523
Lime,	2·3908	——tragacanth,	1.3161
Alumine,	2.	Extract of liquorice,	1.7228
Zircone,	4.3	——— catechu,	1.4573
Silex,	2.66	Camphor,	0.9887
Soda, strontia, gadolinite, glucine, unknown.		Caoutchouc,	0.9335
		Cork,	0.2400
Tallow,	0.9419		

FLUIDS.

Water,	1.0000	Alcohol,	0.8293
Sulphuric acid,	2.1250	Sulphuric ether,	0.7394
Nitric acid,	1.5800	Oil of turpentine,	0.8697
Muriatic acid,	1.1940	—— olives,	0.9153
Acetous do.	1.0135	—— almonds,	0.9170
Acetic do.	1.0626	Linseed oil,	0.9403
Water saturated with ammonia,	0.8970	Whale oil,	0.9233

TABLE III.

Exhibiting the Solubility of Saline and other Substances in 100 Parts of Water, at the Temperature of 60° and 212°

Acids	60°	212°
Sulphuric,	unlimited.	unlimited.
Nitric,	do.	do.
Acetous,	do.	do.
Prussic,	do.	do.
Phosphoric, Acetic, Tartareous, Malic, Lactic, Laccic,	very soluble, proportion not determined.	
Arsenic,	150	
Citric,	133	200
Oxalic,	50	100
Gallic,	8.3	66
Boracic,		2
Mucous,	0.84	1.25
Succinic,	4 / 1.04	50
Suberic,	0.69	50
Camphoric,	1.04	8.3
Benzoic,	0.208	4.17
Molybdic,		0.1
Chromic, unknown.		
Tungstic, insoluble.		
Salifiable Bases.		
Potash, Soda,	very soluble, proportion not known.	
Barytes,	5	50
——crystallized,	57	any quantity.
Strontia,	0.006	
——crystallized,	1.9	50
Lime,	0.2	
Salts.		
Sulphate of potash,	6.25	20
Super-sulphate of potash,	50	100+
Sulphate of soda,	37.4	125
——ammonia,	50	100

Temperature,	60°	212°
Sulphate of magnesia, - -	100	133
——— alumine, very soluble, proportion unknown.		
Super-sulphate of alumine and potash,	alum, 5	133
Super-sulphate of alumine and ammonia,		
Nitrate of barytes, - -	8	25
——— potash, - -	14.25	100
——— soda, - -	33	100+
——— strontia, - -	100	200
——— lime, - -	400	any quantity.
——— ammonia, - -	50	200
——— magnesia, - -	100	100+
Muriate of barytes, - -	20	
——— potash, - -	33	
——— soda, - -	35.42	36.16
——— strontia, - -	150	any quantity.
——— lime, - -	200	
——— ammonia, - -	33	
——— magnesia, - -	100	
Oxy-muriate of potash, -	6	40
Phosphate of potash very soluble.		
——— soda, - -	25	50
——— ammonia, - -	25	25+
——— magnesia, - -	6.6	
Sub-borate of soda, - -	8.4	16.8
Carbonate of potash, - -	25	83.3
——— soda, - -	50	100+
——— magnesia, -	2	
——— ammonia, -	50+	100
Acetite of potash, - -	100	
——— soda, - -	35	
——— ammonia very soluble.		
——— magnesia, do.		
——— strontia, - -		40.8
Super-tartrite of potash, -	1.67	3.3
Tartrite of potash, - -	25	
——— and soda, -	25	
Super-oxalate of potash, -		10
Citrate of potash very soluble.		
Prussiate of potash and iron.		
Nitrate of silver very soluble.		

Temperature,	60°	212°
Oxymuriate of mercury (cor. sub.)	5	50
Sulphate of copper, - -	25	50
Acetite of copper very soluble.		
Sulphate of iron, - -	50	133
Muriate of iron very soluble.		
Tartrite of iron and potash.		
Acetites of lead and of mercury.		
Sulphate of zinc, - -	44	44+
Acetite of zinc very soluble.		
Tartrite of antimony and potash,	1.25	2.5
Alkaline soaps very soluble.		
Sugar, - - - -	100	any quantity.
Gum very soluble.		
Starch, - - - -	0	very soluble.
Jelly, - - -	sparingly,	abundantly.
Gelatin, - - -	soluble,	more so.
Urea very soluble.		

Salts not soluble in 100 *times their weight of water.*

Sulphates of barytes, strontia, and lime, and sub-sulphate of mercury.
Phosphates of barytes, strontia, lime, magnesia, and mercury.
Fluate of lime.
Carbonates of barytes, strontia, and lime.
Muriates of lead, silver, and mercury, (Calomel).
Sub-acetite of copper.

TABLE IV.

Showing the Solubility of Saline and other Substances in 100 *Parts of Alcohol, at the Temperature of* 176°

All the acids, except the sulphuric, nitric, and oxymuriatic, which decompose it, and the phosphoric and metallic acids.
Potash, soda, and ammonia, very soluble.
Red sulphate of iron.

Muriate of iron, - - - - -	100
——— lime, - - - - -	100
Nitrate of ammonia, - - - -	89.2
Oxy-muriate of mercury, - - -	88.3
Nitrate of silver, - - - - -	41.7

Refined sugar,	24.6
Muriate of ammonia,	7.1
Arseniate of potash,	3.75
Nitrate of potash,	2.9
Arseniate of soda,	1.7

Muriate of soda (Mr. Chenevix)
Alkaline soaps.
Magnesian do.
Extract.
Tannin.
Volatile oils.
Adipocere.
Resins.
Camphor.
Urea.

Substances insoluble in Alcohol.

Earths.
Phosphoric and metallic acids.
Almost all the sulphates and carbonates.
The nitrates of lead and mercury.
The muriates of lead, silver, and soda.
The sub-borate of soda.
The tartrite of soda and potash, and the super-tartrite of potash.
Fixed oils, wax, and starch.
Gum, caoutchouc, suber, lignin, gelatin, albumen, and fibrin.

TABLE V.

Shewing the Weight of the different Gases *aborbed by* 100 *Parts of Water.*

Muriatic acid,	100.
Ammonia,	34.
Sulphurous acid,	3.96
Nitrous oxyd,	0.27
Carbonic acid,	0.18
Nitric Oxyd,	0.16

Carbonic oxyd,
Oxygen,
Hydrogen,
Sulphuretted hydrogen,
Carburetted hydrogen, } unknown.

TABLE VI. *Shewing the Specific Gravity of Mixtures of Alcohol and Water.**

Centesimal Parts of the Mixture.		SPECIFIC GRAVITY. According to Chaussier	According to Gilpin, (last Table.)
Alcohol	100	0.7980	0.825
	95	0.8165	0.83887
	90	0.8340	0.85244
	85	0.8485	0.86414
	80	0.8620	0.87606
	75	0.87525	0.88762
	70	0.8880	0.89883
	65	0.9005	0.90941
	60	0.9120	0.91981
	55	0.9230	0.92961
	50	0.9334	0.93882
	45	0 94265	0.94726
	40	0.9514	0.95493
	35	0.95865	0.96158
	30	0.96535	0.96736
	25	0.97035	0.97239
	20	0.97605	0.97723
	15	0.9815	0.98218
	10	0.9866	0 98737
	5	0.99335	0.99327
	0	0.99835	1.00000

TABLE VII. *Shewing the Component Parts of Nitric Acid of different Colours and Densities, by Mr. Davy.*

100 Parts.	Spec. Grav.	COMPONENT PARTS. Nitric Acid.	Water.	Nitrous Gas.
Solid nitric acid	1.504	91.55	8.45	—
Yellow nitrous	1.502	90.5	8.3	1.2
Bright yellow	1.500	88.94	8.10	2.96
Dark orange	1.480	86.84	7.6	5.56
Light olive	1.479	86.0	7.55	6.45
Dark olive	1.478	85.4	7.5	7.1
Bright green	1.476	84.8	7.44	7.76
Blue green	1.475	84.6	7.4	8.00

* Chaussier's alcohol had the specific gravity of 0.798; and Gilpin's, that of 0.825. The Tables of Gilpin are to be found in the Philosophical Transactions for 1794.

TABLE VIII.

Shewing some of the Properties of Metals; the Proportion of Oxygen with which they combine; and the Colours of their Oxyds.

Metals.	Colour.	Specific Grav.	Fusing Point.	No. of Oxids	Colours of Oxids.	Prop. of Oxigen
Gold	Yellow	19.361	32 W.	1 2	Purple Yellow	 10.
Platina	White	23.000	+170 W.	1 2	Green Brown	.7½ 0.15
Palladium	White	11.871	+160 W.	1 2	Blue Yellow?	
Rhodium	White	+ 11.	+160 W.	1 2	Yellow	
Iridium	White		+160 W.	1 2	Blue? Red?	
Osmium	Blue			1	Transparent	
Silver	White	10.510	22 W.	1 2	Olive	12.8
Mercury	White	13.568	—39 F.	1 2 3	Black Red	5. 11.
Copper	Red	8.895	27 W.	1 2	Red Black	13. 25.
Iron	Blue-gray	7.788	158 W.	1 2 3	White Black Red	29. 31.6 45.
Tin	White	7.299	442 F.	1 2	Gray White	25. 38.3

TABLE, *shewing some of the Properties of Metals, &c. Continued.*

Metals.	Colours.	Specific Grav.	Fusing Point.	No. of Oxids	Colours of Oxids	Prop of Oxige
Lead	Bluish-white	11.352	612 F.	1 2 3 4	Yellow Red Brown	10.6 13.6 25.
Nickel	White	8.666	+160 W.	1 2	Green Black	28.
Zinc	White	6.861	680 F.	1 2	Yellow White	13.6 25.
Bismuth	White	9.822	476 F.	1 2	Yellow	12.
Antimony	Gray	6.712	809 F.	1 2	White Do.	22.7 30.
Arsenic	White	8.310	+ 400 F?	1 2	White Ditto (acid)	33. 53.
Cobalt	White	7.700	130 W.	1 2 3	Blue Green Black	
Manganese	White	6.850	+160 W.	1 2 3	White Red Black	25. 35. 66.6
Molybdena	Gray	8.600	+170 W.	1 2 3 4	Light brown Violet Blue White	 34. 50
Tellurium	White	6.115	+ 612 F.	1 2	White	
Tungsten	Grayish-white	17.6	+170 W.	1 2	Black Yellow	25.
Uranium	Gray	9.000	+170 W	1 2	Black Yellow	5.17 28.

TABLE, *showing some of the Properties of Metals, &c. Continued.*

Metals.	Colour.	Specific Gravity.	Fusing point.	No. of Oxyds.	Colours of Oxdys.	Prop. of Oxygen.
Titanium	Red	4	+170 W.	1 2 3	Blue Red White	
Chromium	White		+170 W.	1 2 3	Green Brown Red	200
Columbium					White	
Tantalium					White	
Cerium	White			1 2	White Red	

N. B. The numbers, in the last column of the foregoing Table, denote the quantity of oxygen with which 100 parts of each metal combine. Thus, to form the black oxyd of iron, 100 parts of the metal absorb 37 oxygen, and afford 137 of an oxyd, which, in 100 parts, contain 27 of oxygen. In the column shewing the fusing point, W. added to the numerals, denote the degrees of Wedgwood's pyrometer, and F. those of Fahrenheit's thermometer.

TABLE IX. ***Exhibiting the Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents.***

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with sulphuretted hydrogen.	Hydro-Sulphurets.
Copper	Bright reddish-brown.	Brownish.	Black.	Black.
Iron 1. Green salts 2. Red salts	White changing to blue. Deep blue.	No precipitate. Black.	Not precipitated.	Black.
Nickel	Green.	Grayish-white.	Not precipitated.	Black.
Tin	White.	No precip.	Brown.	Black.
Lead	White.	White.	Black.	Black.
Zinc	White.	No precip.	Yellow.	White.
Bismuth	White.	Orange.	Black.	Black.
Antimony	White.	A white oxyd merely from dilution.	Orange.	Orange.
Tellurium	No precip.	Yellow.		Blackish.
Arsenic	White.	Little change.	Yellow.	Yellow.
Cobalt	Brownish-yellow.	Yellowish-white.	Not precipitated.	Black.
Manganese	Yellowish-white.	No precip.	Not precipitated.	White.
Chrome	Green.	Brown.		Green.
Molybdena	Brown.	Deep-brown.	Brown.	

TABLE, *exhibiting the Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents—Continued.*

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Gold	Yellowish-white.	Solution turned green. Precipitate brown of reduced gold.	Yellow.	Yellow.
Platina	No precipit. but an orange coloured one by pruss. of mercury.	Dark-green, becoming paler.	Precipitated in a metallic state.	
Silver	White	Yellowish brown	Black	Black.
Mercury	White, changing to yellow.	Orange yellow.	Black	Brownish-black.
Palladium	Olive.* Deep orange.†		Dark-brown	Dark-brown.
Rhodium	No precip.			No precip.
Iridium	No precipitate. Colour discharged.	No precipitate. Colour of solutions discharged.		
Osmium		Purple, changing to deep vivid blue.		

* Chenevix. † Wollaston.

Table, *exhibiting the Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents—Continued.*

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Uranium	Brownish-red.	Chocolate.		Brownish yellow.
Tungsten				
Titanium	Grass-green, with a tinge of brown.	Reddish-brown.	Not precipitated.	Grass-green.
Columbium	Olive.	Orange.		Chocolate.
Tantalium				
Cerium		Yellowish.		Brown, becoming deepgreen

Table X. *Shewing the maximum Quantity of Oxygen taken up by different Substances.*

SIMPLE COMBUSTIBLES.

100 Hydrogen unite with	-	597.7 Oxygen.
100 Carbon - - - -		257.
100 Azote - - - -		236.
100 Muriatic acid - - -		194.
100 Phosphorus - - -		154.
100 Sulphur - - - -		71.3

METALS.

100 Chrome combine with	-	200. Oxygen.
100 Iron - - -		92.3
100 Manganese - - -		66.

100 Arsenic	53. Oxygen.
100 Tin	38.
100 Antimony	30.
100 Zinc, 100 Copper, 100 Lead, 100 Tungsten	25.
100 Mercury	17.6
100 Platina	15.
100 Silver	12.8
100 Bismuth	12.
100 Gold	10.

☞ The following tables are copied from Henry's Elements of Experimental Chemistry, sixth London edition, 1810.

XI.—*Table of the Force of Steam at different Temperatures of Fahrenheit's Scale from actual Experiment.*

(Betancourt in Prony's Architecture Hydraulique.)

Temperature.	Force in English Inches of Mercury.	Temperature.	Force in English Inches of Mercury.
32	0	162	9.07
42	.08	172	11.0
52	.21	182	14.9
62	.38	192	18.7
72	.58	202	23.7
82	.87	212	29.8
92	1.26	222	37.4
102	1.74	232	46.5
112	2.37	242	57.3
122	3.16	252	69.7
132	4.16	262	83.6
142	5.43	272	97.1
152	7.00	282	108.

In the fifth volume of "Memoirs of the Manchester Society, the following valuable table of the force of vapour for each degree of Fahrenheit, is given by Mr. Dalton; the numbers below 212° from experiment, and the higher numbers from calculation. Mr. Betancourt, however, professes to have obtained all the above results from actual experiment.

Table of the Force of Vapour from Water in every Temperature from that of the Congelation of Mercury, or 40° below zero of Fahrenheit, to 325°.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
—40	.013	30	.186	64	.597
—30	.020	31	.193	65	.616
—20	.030			66	.635
—10	.043	32	.200	67	.655
		33	.207	68	.676
0	.064	34	.214	69	.698
1	.066	35	.221	70	.721
2	.068	36	.229	71	.745
3	.071	37	.237	72	.770
4	.074	38	.245	73	.796
5	.076	39	.254	74	.823
6	.079	40	.263	75	.851
7	.082	41	.273	76	.880
8	.085	42	.283	77	.910
9	.087	43	.294	78	.940
10	.090	44	.305	79	.971
11	.093	45	.316	80	1.00
12	.096	46	.328	81	1.04
13	.100	47	.339	82	1.07
14	.104	48	.351	83	1.10
15	.108	49	.363	84	1.14
16	.112	50	.375	85	1.17
17	.116	51	.388	86	1.21
18	.120	52	.401	87	1.24
19	.124	53	.415	88	1 28
20	.129	54	.429	89	1.32
21	.134	55	.443	90	1.36
22	.139	56	.458	91	1.40
23	.144	57	.474	92	1.44
24	.150	58	.490	93	1.48
25	.156	59	.507	94	1.53
26	.162	60	.524	95	1.58
27	.168	61	.542	96	1.63
28	.174	62	.560	97	1.68
29	.180	63	.578	98	1.74

Table of the Force of Vapour, &c.—Continued.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
99	1.80	138	5.44	177	14.22
100	1.86	139	5.59	178	14.52
101	1.92	140	5.74	179	14.83
102	1.98	141	5.90	180	15.15
103	2.04	142	6.05	181	15.50
104	2.11	143	6.21	182	15.86
105	2.18	144	6.37	183	16.23
106	2.25	145	6.53	184	16.61
107	2.32	146	6.70	185	17.00
108	2.39	147	6.87	186	17.40
109	2.46	148	7.05	187	17.80
110	2.53	149	7.23	188	18 20
111	2.60	150	7.42	189	18.60
112	2.68	151	7.61	190	19.00
113	2.76	152	7.81	191	19.42
114	2.84	153	8.01	192	19.86
115	2.92	154	8.20	193	20.32
116	3.00	155	8.40	194	20.77
117	3 08	156	8.60	195	21.22
118	3.16	157	8.81	196	21.68
119	3.25	158	9.02	197	22 13
120	3.33	159	9.24	198	22.69
121	3.42	160	9.46	199	23.16
122	3.50	161	9.68	200	23.64
123	3.59	162	9.91	201	24.12
124	3.69	163	10.15	202	24.61
125	3.79	164	10.41	203	25.10
126	3.89	165	10.68	204	25.61
127	4.00	166	10.96	205	26.13
128	4.11	167	11.25	206	26.66
129	4.22	168	11.54	207	27.20
130	4.34	169	11.83	208	27.74
131	4.47	170	12.13	209	28 29
132	4.60	171	12.43	210	28.84
133	4.73	172	12 73	211	29.41
134	4.86	173	13.02	212	30.00
135	5.00	174	13.32		
136	5.14	175	13.62	213	30.60
137	5.29	176	13.92	214	31.21

Table of the Force of Vapour, &c.—Continued.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
215	31.83	252	60.05	289	98.96
216	32.46	253	61.00	290	100.12
217	33.09	254	61.92	291	101.28
218	33.72	255	62 85	292	102.45
219	34.35	256	63.76	293	103.63
220	34.99	257	64.82	294	104.80
221	35.63	258	65.78	295	105.97
222	36.25	259	66.75	296	107.14
223	36.88	260	67 73	297	108.31
224	37.53	261	68.72	298	109.48
225	38.20	262	69.72	299	110.64
226	38.89	263	70 73	300	111.81
227	39.59	264	71.74	301	112.98
228	40.30	265	72 76	302	114.15
229	41.02	266	73.77	303	115.32
230	41.75	267	74.79	304	116.50
231	42.49	268	75 80	305	117.68
232	43.24	269	76.82	306	118.86
233	44.00	270	77.85	307	120.03
234	44.78	271	78.89	308	121.20
235	45 58	272	79.94	309	122.37
236	46.39	273	80.98	310	123.53
237	47.20	274	82.01	311	124.69
238	48.02	275	83.13	312	125.85
239	48.84	276	84.35	313	127.00
240	49.67	277	85.47	314	128.15
241	50.50	278	86.50	315	129.39
242	51.34	279	87.63	316	130.43
243	52.18	280	88.75	317	131.57
244	53.03	281	89.87	318	132.72
245	53.88	282	90.99	319	133.86
246	54.68	283	92.11	320	135.00
247	55.54	284	93.23	321	136.14
248	56.42	285	94.35	322	137.28
249	57.31	286	95.48	323	138.42
250	58.21	287	96 64	324	139.56
251	59.12	288	97.80	325	140.70

XII.—*Table of the Expansion of Air by Heat.*

(Communicated by Mr. Dalton.)

Fahren.		Fahren.		Fahren.	
32	1000	59	1064	86	1123
33	1002	60	1066	87	1125
34	1004	61	1069	88	1128
35	1007	62	1071	89	1130
36	1009	63	1073	90	1132
37	1012	64	1075	91	1134
38	1015	65	1077	92	1136
39	1018	66	1080	93	1138
40	1021	67	1082	94	1140
41	1023	68	1084	95	1142
42	1025	69	1087	96	1144
43	1027	70	1089	97	1146
44	1030	71	1091	98	1148
45	1032	72	1093	99	1150
46	1034	73	1095	100	1152
47	1036	74	1097	110	1173
48	1038	75	1099	120	1194
49	1040	76	1101	130	1215
50	1043	77	1104	140	1235
51	1045	78	1106	150	1255
52	1047	79	1108	160	1275
53	1050	80	1110	170	1295
54	1052	81	1112	180	1315
55	1055	82	1114	190	1334
56	1057	83	1116	200	1354
57	1059	84	1118	210	1372
58	1062	85	1121	212	1376

XIII.—*Table of the Expansion of Liquids by Heat.*

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid	Nitric Acid.	Water.	Oil of Turpen.	Alcohol.
32°	100000	100000	. .	. .	. .	. .	100000
40	100081	. .	99752	99514	. .	. .	100539
50	100183	. .	100000	100000	100023	100000	101105
60	100304	. .	100279	100486	100091	100460	101688
70	100406	. .	100558	100990	100197	100993	102281
80	100508	. .	100806	101530	100332	101471	102890
90	100610	. .	101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104162
110	100813	. .	101540	103196	. .	102943	. .
120	100915	. .	101834	103776	101404	103421	. .
130	101017	. .	102097	104352	. .	103954	. .
140	101119	. .	102320	105132	. .	104573	. .
150	101220	. .	102614	. .	102017	. .	. .
160	101322	. .	102893	. .	. .	. .	. .
170	101424	. .	103116	. .	. .	. .	. .
180	101526	. .	103339	. .	. .	. .	. .
190	101628	. .	103587	. .	103617	. .	. .
200	101730	. .	103911	. .	. .	. .	. .
212	101835	107250	. .	. .	104577	. .	. .

XIV.—*Table of the Expansion of Water by Heat.*

(From Mr. Dalton's New System of Chemical Philosophy.)

Temperature.	Expansion.	Temperature.	Expansion.
12° Fahren.	100236	122° Fahren.	101116
22	100090	132	101367
32	100022	142	101638
42	100000	152	101934
52	100021	162	102245
62	100083	172	102575
72	100180	182	102916
82	100312	192	103265
92	100477	202	103634
102	100672	212	104012
112	100880		

XV.—*Table of the Expansion of Solids by Heat.*

Temp.	Platina.†	Antimon.	Steel.	Iron.	Cast Iron.	Bismuth.
32°	120000	120000	120000	120000	120000	120000
212	120104	120130	120147	120151		120167
White heat*			123428	121500	122571	

	Copper.	Cast Brass.	Brass Wire.	Tin.	Lead.	Zinc.
32°	120000	120000	120000	120000	120000	120000
212	120204	120225	120232	120298	120344	120355

	Hammered Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin‡ 1
32°	120000	120000	120000	120000	120000	120000
212	120373	120323	120301	120247	120274	120218

Expansion of Glass.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	100°	100023	167°	100056
50	100006	120	100033	190	100069
70	100014	150	100044	212	100083

* Rinman. † Borda.

‡ The metal, whose expansion is here given, was an alloy composed of three parts of copper, and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus, in the last column but two, the metal consisted of two parts of brass, alloyed with one of zinc.

XVI.—*Table of Specific Heats.*

(From Mr. Dalton's New System of Chemical Philosophy, Part I.)

GASES.	Equal Weights.	Equal Bulks.
Hydrogen	21.40	.002
Oxygen	4.75	.006
Common air	1.79	.002
Carbonic acid	1.05	.002
Azotic	.79	.001
Aqueous vapour	1.55	.001
LIQUIDS.		
Water	1.00	1.00
Arterial blood	1.03	
Milk (1.026)	.98	1.00
Carbonate of ammon. (1.035)	.95	.98
Carbonate of potash (1.30)	.75	.98
Solution of ammonia (.948)	1.03	.98
Common vinegar (1.02)	.92	.94
Venous blood	.89	
Solut. of common salt (1.197)	.78	.93
Solut. of sugar (1.17)	.77	.90
Nitric acid (1.20)	.76	.96
Nitric acid (1.30)	.68	.88
Nitric acid (1.36)	.63	.85
Nitrate of lime (1.40)	.62	.87
Sulph. acid and water, equal b	.52	.80
Muriatic acid (1.153)	.60	.70
Acetic acid (1.056)	.66	.70
Sulphuric acid (1.844)	.35	.65
Alcohol (.85)	.76	.65
Alcohol (.817)	.70	.57
Sulphuric ether (.76)	.66	.50
Spermaceti oil (.87)	.52	.45
Mercury	.04	.55

SOLIDS.	Equal Weights.	Equal Bulks.
Ice	.90?	.83
Dried woods, and other vegetable substances, from		
.45 to	.65	
Quicklime	.30	
Pitcoal (1.27)	.28	.36
Charcoal	.26	
Chalk	.27	.67
Hydrat. lime	.25	
Flint glass (2.87)	.19	.55
Muriate of soda	.23	
Sulphur	.19	
Iron	.13	1.00
Brass	.11	.97
Copper	.11	.98
Nickel	.10	.78
Zinc	.10	.69
Silver	.08	.84
Tin	.07	.51
Antimony	.06	.40
Gold	.05	.97
Lead	.04	.45
Bismuth	.04	.40
Oxydes of the metals surpass the metals themselves, according to Crawford.		

XVII.—*Kirwan's Table, showing the Composition of Salts.*

COMPONENT PARTS.

SALTS.	BASIS.	ACID.	WATER.	STATE.
Carbonate of potash	41.	43.	16.	Crystallized.
Pearlash	60.	30.	6.	Dry.
Carbonate of soda	21.58	14.42	64.	Fully crystallized.
ditto	59.86	40.05		Desiccated.
barytes	78.	22.		Natural or ignited.
strontian	69.5	30.		Natural or ignited.
lime	55.	45.		Natural if pure, or artificial ignited.
magnesia	25.	50.	25.	Crystallized.
common do	45.	34.	21.	Dried at 80°.
Sulphate of potash	54.8	45.2		Dry.
soda	18.48	23.52	58.	Fully crystallized.
ditto	44.	56.		Desiccated at 700°.
ammonia	14.24	54.66	31.1	
barytes	66.66	33.33		Natural and pure, artificial ignited.
strontian	58.	42.		Natural and pure, artificial ignited.
lime	32.	46.	22.	Dried at 66°.
ditto	35.23	50.39	14.38	Dried at 170°.
ditto	38.81	55.84	5.35	Ignited.
ditto	41.	59.		Incandescent.
magnesia	17.	29.35	53.65	Fully crystallized.
ditto	36.68	63.32		Desiccated.
Alum	12.ignited	17.65	51. of crystals + 19.24 in the earth	Crystallized.
Ditto	63.75	36.25		Desiccated at 700°.

Table, showing the Composition of Salts.—Continued.

COMPONENT PARTS.

SALTS.	BASIS.	ACID.	WATER.	STATE.
Nitrate of potash	51.8	44.	4.2 of Composition	Dried at 70°.
soda	40.58	53.21	6.21 of Composition	Dried at 400°.
ditto	42.34	57.55		Ignited.
ammonia	23.	57.	20.	
barytes	57.	32.	11.	Crystallized.
strontian	36.21	31.07	32.72	Crystallized.
lime	32.	57.44	10.56	Well dried, that is, in air.
magnesia	22.	46.	22.	Crystallized.
Muriate of potash	64.	36.		Dried at 80°.
soda	53.	47. aqueous, 38.88 real		Dried at 80°.
ammonia				Crystallized.
ditto	25.	42.75	32.25	Sublimed.
barytes	64.	20.	16.	Crystallized.
ditto	76.2	23.8		Desiccated.
strontian	40.	18.	42.	Crystallized.
ditto	69.	31.		Desiccated.
lime	50.	42.	8.	Red hot.
magnesia	31.07	34.59	34.34	Sensibly dry.

XVIII.—*Table of Incompatible Salts.**

SALTS.	INCOMPATIBLE WITH
1. Fixed alkaline sulphates	Nitrates of lime and magnesia, Muriates of lime and magnesia.
2. Sulphate of lime .	Alkalies, Carbonate of magnesia, Muriate of barytes.
3. Alum	Alkalies, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia	Alkalies, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron .	Alkalies, Muriate of barytes, Earthy carbonates.
6. Muriate of barytes	Sulphates, Alkaline carbonates, Earthy carbonates.
7. Muriate of lime .	Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Muriate of magnesia	Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime . .	Alkaline carbonates, Carbonates of magnesia and alumine, Sulphates, except of lime.

XIX.—*Quantity of real Acid taken up by mere Alkalies and Earths (Kirwan.)*

100 Parts.	Sulphuric.	Nitric.	Muriatic.	Carbonic Acid.
Potash	82.48	84.96	56.3	105, almost
Soda	127.68	135.71	73.41	66.8
Ammonia	383.8	247.82	171.	Variable
Baryt.	50.	56.	31.8	282.
Strontia	72.41	85.56	46.	43.2
Lime	143.	179.5	84.488	81.81
Magnesia	172.64	210.	111.35	200. Fourcroy
Alumine	150.9			335, nearly, Bergman.

* That is, salts which cannot exist together in solution, without mutual decomposition.

XX.—*Quantity of Alkalies and Earths taken up by 100 Parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, Saturated (Kirwan.)*

100 Parts.	Potash.	Soda.	Ammonia.	Baryt.	Strontia.	Lime.	Mag.
Sulphuric	121.48	78.32	26.05	200.	138.	70.	57.92
Nitrous	117.7	73.3	40.35	178.12	116.86	55.7	47.64
Muriatic	177.6	136.2	58.48	314.46	216.21	118.3	898.
Carbonic	95.1	149.6		354.5	231.+	122.	50.

XXI.—*Table, by Richter, of the Quantity of each Base required for the Saturation of the different Acids.*

(From Berthollet's *Statique Chimique*, 1re *Partie*, p. 136.)

The experiments, from which the following table was deduced, we are assured by Berthollet, were the principal occupation of Richter from the year 1791 to 1800; and from the attention with which they were performed, appear to be deserving of considerable confidence. An example will best explain the method of using the table. Take the article *potash* in the first column, opposite to which is placed the number 1605. The numbers in the other column show how much of each acid is required to saturate 1605 parts of potash, *viz.* 427 parts of fluoric acid, 577 of carbonic acid, &c. In a similar manner, take any acid in the second column, the oxalic for instance; the first column shows how much of each base effects the saturation of 755 parts of oxalic acid, *viz.* 525 of alumine, 615 of magnesia, &c.

BASES.		ACIDS.	
Alumine	525	Fluoric	427
Magnesia	615	Carbonic	577
Ammonia	672	Sebacic	706
Lime	793	Muriatic	712
Soda	859	Oxalic	755
Strontites	1329	Phosphoric	979
Potash	1605	Formic	988
Barytes	2222	Sulphuric	1000
		Succinic	1209
		Nitric	1405
		Acetic	1480
		Citric	1563
		Tartaric	1691

DESCRIPTION OF THE PLATES.

PLATE I.

Fig. 1, 2, 3, 4, represent crucibles. It is absolutely necessary for the operative chemist to have a few crucibles of pure silver, as well as one or two of platina. Those of earthen-ware should be of various sizes and shapes. Some crucibles are round, fig. 3, others triangular, fig. 1, furnished with a spout, for pouring out the melted matters; those crucibles that belly out in the middle, 4, are called assay crucibles, or in commerce skettle pots. Fig. 2 is a section of a large crucible with its cover.

The crucibles known in commerce by the name of *Hessian*, are in every respect superior to those manufactured in this country. The black-lead crucibles made of clay and black lead are very durable, but they cannot be used for alkaline fluxes or saline matters. Crucibles which ring clearly when struck, and which are of an uniform thickness, and have a reddish brown colour, without black spots, are the best; they should never be placed upon the grate of the furnace, but always on a piece of brick or other support of stone, or earthen-ware, called a crucible stand.

Fig. 5 and 6 represent crucible stands.

Fig. 7 and 8, cupels or small shallow saucers from $\frac{1}{2}$ inch to 1 inch broad, made of phosphate of lime or bone ashes, for the process of cupellation or assaying of metals.

Fig. 9 and 10 represent muffles used in the assay or cupelling furnace. The muffle is, in fact, a small furnace,

included within another larger one, to receive the cupel fig. 7 or 8, in the process of cupellation, or for the roasting of ores or other substances which are intended to be exposed to a red or white heat, without coming in contact with the fuel, but having free contact with the air. Muffles are generally made of crucible ware. Their form is half a cylinder cut length-ways, open in front and closed behind, and provided with a bottom. The larger muffles, fig. 10, are generally provided with slits or side apertures, to admit the heat and air more readily.

Fig. 11 a pair of crucible tongs, for removing circular and triangular crucibles out of the fire, without danger of breaking them.

Fig. 12 and 13 represent a cupelling or assay furnace. The form of it is an oblong square, its dimensions being regulated by that of the muffle, which should go home to the back by one inch, its front edge lodging on the mouth of the furnace. On each side of the muffle two or three inches must be left, to permit the fuel to pass readily underneath, where there should also be a similar space. On the other side a stoke hole must be left for stirring the fire occasionally; the situation of the view does not admit of exhibiting this aperture. Before the muffle there is a projecting ledge or shelve shown at *f*, which is very useful to support and to heat the cupel, or other substance that is intended to be introduced into the muffle. Two twelve-inch paving tiles worked in along with the bricks answer this purpose. In figure 13, *a* shows the ash-pit, and in figure 12, the same is marked *d;* in both figures *c* shows the grate, *d* the muffle, *e* the aperture for introducing the muffle, and at fig. 12, *g* the cover.

Fig. 14. represents Chenevix's wind furnace. This furnace Mr. Chenevix describes as follows: "I have constructed a wind furnace which, in some respects, is preferable to that of the usual form. The sides of the furnace, instead of being perpendicular, are inverted; so that the hollow space is pyramidal. At the bottom the space is 12 inches square, and at the top only 8. The perpendicular height is 17 inches from the top to the grate. This form unites the following advantages: 1. A large surface is exposed to the air, which having an easy access,

rushes through the fuel with great rapidity. 2. The inclined sides act as reverberators. 3. The fuel falls of itself, and is always close to the grate. *a* represents the grate: *c c* are two fire bricks which can be let in at pleasure, to contract the capacity; *b* is a second grate which can be placed on the bricks *c c* for occasional purposes; *d d* are fire bricks which may be placed on the grate *a*, to diminish the capacity of this part of the furnace; *e* represents the cover. Both sets of bricks below and above the grate *b*, should be ground to the slope of the furnace.

Fig. 15 and 16, mortars. The mortars met with in the shops are frequently ill constructed. The bottom of all mortars should be concave, and their sides neither so inclined as to allow the substance operated on to fall to the bottom, between each stroke of the pestle, nor so perpendicular as to collect it too much together, and retard the operation.

Fig. 16, a perspective view and section of a mortar. An agate mortar of the shape as shown fig. 15, is very useful for the trituration of siliceous stones, &c.

Fig. 17, Davy's apparatus for the analysis of soils. See page 371, Vol. II.

Fig. 18, a retort funnel, for introducing fluids into retorts preventing the neck of the latter from becoming soiled.

Fig. 19, an improved blow-pipe. It consists of a conical tube furnished with a small pipe near the base, to which jets or caps of different perforations may be adapted. The air is forced into the blow-pipe by the mouth of the operator, or by means of a bladder or double bellows attached to the instrument. The substance to be fused must be placed upon a piece of charcoal, or held in a small spoon made of pure silver or platina. The quantity of the substance to be examined by means of the blow-pipe ought not to exceed the size of a pepper corn.

Fig. 20 represents an iron mortar of an improved form, with its cover. It differs from the ordinary shape of mortars, in being nearly circular instead of conical; by this means substances are more readily comminuted, and are not so subject to be thrown out of the mortar by the effort of the pestle: tenacious substances are not so subject to

cake, and a better effect is produced in many instances by giving a rotatory motion to the pestle, which cannot be effectually accomplished in the mortar of the usual forms. To prevent the finest and lightest parts of the powdered substance from escaping, and to defend the operator from the effects of disagreeable or noxious substanced, the top of this mortar is so constructed as to admit a wooden cover within a rim or groove, a mode more effectual than the old contrivance of covering the orifice of the mortar with a mere perforated cover. The pestle has a hole in the upper extremity, in order to suspend it if required.

PLATE II.

Fig. 1 and 2 represent a sand-bath or reservoir for carrying on a number of chemical processes at the same time, particularly such as distillations, evaporations, digestions, &c. The sand-bath is generally constructed of masonry. At the front is a rim made of free-stone or sheet iron about 4 inches deep, fastened, or let in, at each end into the wall. The bed *e e* is formed of cast-iron plates which rest upon each other in corresponding rabbets. The advantage of several plates over one large one is the cheapness and facility with which they are replaced if cracked by the heat, an accident of not unfrequent occurrence. The joints of the plates are secured by loam or clay, which effectually prevents the sand from falling through. The fire place is shown by *b*; *a* is the ash-pit. The flame and smoke circulate first through the flue *c*, and then through the returning flue *d*, which conveys the smoke to the chimney *g*. In constructing the flue beneath the grate, a row of bricks set edge-ways answers the purpose, and serves also to support the inner edge of the plates.

Fig. 3, a hydrostatic funnel for introducing fluids into air-tight vessels, especially when attended with the extrication of a gazeous fluid. It is evident that any portion of fluid poured into the funnel 3, more than sufficient to fill the two first parts of the bent tube, up to the level *z*, will escape by the lower extremity *b*; at the same time

no gas can return through this funnel, unless its pressure be able to overcome the resistance of a column of fluid of the height of the leg of the funnel marked *y*, *z*, 3.

Fig. 4 is another contrivance for the same purpose. It consists of a common glass funnel: in the neck of which is inserted a glass rod with a conical point, which regulates the passage of the fluid through the funnel, according to the firmness with which it is introduced.

Fig. 5, Pepy's freezing apparatus for the congelation of mercury, and other experiments on artificial cold. It consists of an exterior and interior oval vessel of japanned iron. The interior vessel *a a* being one inch less in every direction than the outer one, *b b*, *c c* are detached circular vessels, placed in the interior one, for containing the freezing mixtures. This apparatus is very convenient for exhibiting the freezing of quicksilver during the heat of summer. The freezing mixture then employed may consist of sulphate of soda and diluted sulphuric acid: but when ice can be procured it should be preferred, and used in the pulverized state with muriate of lime. See freezing mixtures, page 116, vol. i. When the apparatus is to be used with sulphate of soda and dilute sulphuric acid, it is adviseable to dilute the acid the preceding day, in order that it may be of the same temperature as the surrounding air, when the experiment is to be performed.

This being done, let two phials of about four ounces capacity of water be filled with the diluted sulphuric acid, and place them in the middle of the cylindrical vessels *c c*, and then surround them with the pulverized crystals of sulphate of soda, so as to fill the vessels *c c* completely; and then cool down the whole by placing it into the interior vessel *a a* of the apparatus, by surrounding it with a freezing mixture, consisting of sulphate of soda and diluted sulphuric acid. The cover of the apparatus (which is not exhibited in the drawing) is then to be put on, and when the latter is likewise covered over with the same freezing mixture, the whole is suffered to stand for about 25 or 30 minutes. The cover is then taken off, and the cylinders *c c*, containing the sulphate of soda and the diluted acid, are then emptied as expeditiously as possible into the large cylinder *d*, containing the mercury included in a glass tube or phial.

Fig. 6, a test rack or wooden stand, containing glass tubes, for examining small portions of fluids, by the action of reagents or tests, or for dissolving small quantities of earths, or metals, by means of heat over a candle or lamp.

Fig. 7, a filtering-stand, for conveniently supporting funnels; it is furnished with a sliding shelf for supporting glass jars, bottles, basins, or other vessels, and a drawer for containing filtering paper, &c.

Fig. 8, a tube of safety to prevent the bursting of distillatory apparatus, and other vessels, in case of a sudden extrication or condensation of a gazeous fluid. When this apparatus is used, a small quantity of water or mercury is poured through the funnel *p* at the top, until it rises to about the centre of the ball *o*. The instrument being thus adjusted and connected with the distillatory apparatus, either in the tubulature of the retort or receiver, or otherwise, no danger of explosion can ensue; for if a sudden condensation should take place in the apparatus by a diminution of temperature, the fluid will rise in the ball *o*, until the column *g n* be annihilated, when the quantity of air will immediately rush in through *p*, *g*, *n*, *o*, &c. and the water will regain its former equilibrium. On the contrary, if a sudden extrication of gas should take place, it cannot escape by this instrument, because the whole fluid contained in the ball and tube must previously enter the portion of the tube *n*, *p*, where it would form a column of such a height that its pressure could not be overcome.

PLATE III.

Fig. 1 exhibits an improved gazometer. It consists of a cylindrical vessel, made of japanned copper, or iron, A, and a glass cylindrical vessel B. The japanned vessel is furnished with two stop-cocks, one of which is fixed at the top, and the other at the bottom, on opposite sides of the vessel. From the upper cock a tube *c c* runs down to the outside of the vessel A and under its bottom, to the cock *b*. At the centre of the vessel this tube branches upwards through the bottom of the vessel A, and thus a communication is made with the stop-cocks and the glass vessel B, which is suspended in the vessel A by means of

weights and pulleys concealed in the bent tube *a a*. A graduated rod, affixed, by means of a cap, to the vessel B, expresses, by the coincidence of any of its divisions with the aperture *x*, the capacity of the emerged part of the glass vessel, and therefore measures the quantity of gas contained in it. In using this apparatus, the vessel A is filled with water up to the aperture of the tube in the centre of the vessel. The glass vessel B is then depressed till the coincidence of the Zero point of the graduated rod *d* with the aperture *x* indicates its total emersion. This being done, a communication, is then made between the tube *c c* and the apparatus from which the gas proceeds, by opening either of the cocks, and letting the other be shut. The gas thus introduced, will of course proceed by the tube *c c* and enter the vessel B, which, as it becomes filled, will emerge by the pressure of the gas. For breathing or transferring gases from this apparatus, a flexible tube *e* may be joined to either of the stop cocks, and the quantity of gas expended will be measured by the graduated tube, *d*.

Fig. 2, an improved air-holder: it consists of a cylindrical vessel, made of iron, japanned within and without; in the centre of it is a metallic tube *a*, furnished with a stop-cock, one extremity of which descends within half an inch of the bottom of the vessel, or below the projecting tube *b*, and the other extremity passes through the middle of the top or cover, and terminates in a funnel *g*. To charge this air-holder with any gazeous fluid, close the small projecting tube *b* carefully with a cork, and shut the stop-cock *f*. Having done this, fill the air-holder completely, by pouring water into the funnel *g*. This being done, close the other stop-cock likewise, and then withdraw the cork which closed the aperture *b*. It is now obvious that no water can run out till some air be introduced to expel it; when it is therefore wished to be filled, let the neck of the retort, gas bottle, or other apparatus from which the air proceeds, be loosely inserted into the orifice of the tube *b*; the gas, as it is disengaged, will expel the water by the same aperture till the air-holder be completely filled with the gas. If the orifice of the tube *b* be now corked, the gas may be preserved for any length of time. To transfer any portion of the gas from the air-holder, fill the circular basin *c* with wa-

ter, transfer the vessel intended to be filled into this baisn, and then open the cocks; the water will pass into the air-holder through one of the stop-cocks, and a like portion of gas will enter into the vessel intended to be filled. It is obvious, that for this portion the long funnel must be previously removed.

Fig. 3, a convenient apparatus for freezing mercury in the small way, and at a cheap rate. The outer vessel of this apparatus is constructed of wood, furnished with a wooden cover, rabetted in and furnished with a handle. Within this is contained a vessel made of japanned tin *b b*, on which rests a shallow tin pan *c c*. Within this second vessel *b b* is a third, marked, *d*, made of untinned iron. When the apparatus is to be used, a freezing mixture, composed of muriate of lime and snow, or pounded ice, is put into the outer vessel *a a*, so as completely to surround the middle vessel *b b*. Into the latter the vessel *d*, containing the quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow, and muriate of lime previously cooled to 0° Fahrenheit, by an artificial mixture of snow and common salt. The pan *c c* is also filled with these materials, and the wooden cover is then put into its place. The apparatus is now left till the quicksilver is frozen.

Fig. 4, iron rings of different diameters, for cutting off the necks of retorts. They are used by selecting one of the rings which fits the place of the neck of the retort; the ring is then made red-hot, and applied around the neck, at the place intended to be cut: after it has thus been suffered to remain in contact with the glass a few minutes, a neat circular fracture will be effected, or if this should not take place before the ring loses its incandescense, it may be withdrawn; and if a few drops of cold water be suffered to fall on the heated part, the effect will instantly be produced. By this contrivance damaged retorts, which cannot serve the purpose of distillation, may be converted into useful evaporating basins.

Fig. 5, a melting or casting cone, for receiving fused metals: it is best made of brass or bell-metal. For like purposes is fig. 11, called an ingot. Previous to the pouring in of the melted metal into the ingot, or casting

cone, the mould should always be heated, and anointed with tallow (not with oil) or what is still better, it should be covered with a thin coat of chalk.

Fig. 6, a small anvil or stand, for the explosion of fulminating compounds, &c.

Fig. 7, an improved glass syphon, invented by Mr. Howard. This syphon is useful in such cases where it would be disagreeable, dangerous, or impossible, to exhaust the syphon by the common mode of sucking out the air, if I may be allowed such an expression. Its application is therefore very extensive in the laboratory. It consists merely in enlarging the exhausting leg of the syphon to the same calibre as the rest of the instrument; in elevating it a little, and opening its mouth like a funnel. It is scarcely necessary to point out that, to use this syphon, the short leg is, as usual, to be immersed in the liquor intended to be operated upon, and the aperture of the long leg to be closed, whilst the whole instrument is to be filled through the funnel with some of the same fluid.

Fig. 8, 9, and 10, different kinds of chemical tongs, useful for a variety of purposes in the pursuits of the laboratory.

Fig. 12, a chemical thermometer, so constructed that the lower part of the scale board may be turned up by means of a hinge, which renders the instrument very useful for taking the temperature of small quantities, or of mixtures in which acids form a part. The chemical thermometer should be graduated from 40° below 0 up to 600° Fahrenheit.

PLATE IV.

Fig. 1, a table furnace formed of two large black-lead crucibles A B. The lower one, out of which the bottom is cut, and which is furnished with a grate, is fixed into a circular support of strong sheet iron C, furnished with two handles for the convenience of removing it. This part of the furnace forms the ash-pit, and is furnished with a door. The upper crucible has a hole cut in its bottom, into which is inserted an iron tube *d* (of

which part is shown in the drawing) forming the chimney of the furnace, which may be elongated occasionally by an additional piece, so as to increase the draft at pleasure. In order to render this furnace less liable to accidents, a strong iron hoop, *e e*, is fastened round each of the crucibles, the lower of which serves to secure the junction of the two crucibles. In the upper and lower part of the furnace is cut a semi-circular opening for the introduction of charcoal or coke, according to the different processes carried on in the furnace; and the pieces of the crucible, thus removed, may serve as doors to the opening. If an iron sand-bath, with a rim (which is furnished with the furnace) be placed upon the lower crucible, the fuel of course must be introduced through the lower aperture; and thus those chemical processes may be performed which do not admit of the direct application of the fire. But if a reverberatory furnace be required for distilling out of earthen-ware, or coated glass retorts, or for applying an intense heat to bodies, capable of supporting a naked fire, a retort, crucible, &c. may then be introduced, and an intense heat obtained by feeding the furnace, through the opening in the upper crucible. The intensity of the fire may be regulated by means of the door in the ash-pit.

Fig. 2 represents a self-acting blow-pipe, invented by Mr. Hooke, mathematical instrument-maker. A is a hollow sphere for containing highly rectified alcohol, resting upon its shoulder in the ring *g*. Into the sphere A a bent tube *b* is screwed, for conveying alcohol in the gazeous state to the flame at *o*. This tube is continued within the sphere almost to the top. The globe may therefore be nearly filled. At the top of the square there is a safety valve, *c*, to prevent those accidents which might otherwise arise from the expansion of the fluid, in case the heat applied should be too great. The pressure of this valve may be regulated at pleasure by the two milled nuts *e f*, and carrying the steel arm *h*, which presses on the valve *c*. The lamp which heats the alcohol is marked *k*; it is made to adjust to different distances from the sphere A, by sliding up or down between the two pillars *l l*. The distance of the flame *o* from the jet of the tube is regulated by the wick-holder of the lamp, being a little removed from the centre of the brass

piece *m*, which is made to screw, and therefore gives to the wick-holder an eccentric motion. The opening for filling the globe with alcohol is marked *i*. It is closed by means of a milled finger-button, and collar of leather. *n* is a mahogany stand supporting the whole.

Fig. 3, a chemical lamp with large cottons.

Fig. 4 and 5, a perspective view and section of an apparatus for drying the products of chemical analysis, which may also be employed for experiments of congelation.

This apparatus is extremely useful for drying such products as absolutely require a temperature not exceeding 212°; such as fulminating mercury, fulminating silver, and other explosive compounds. The substance to be dried must be placed in the conical glass vessel *b*, and when the vessel *e* is filled with water up to the side tube *d*, the desiccation may be performed without any risk of explosion, or any further trouble, by putting the apparatus over a lamp, and keeping the water in a state of ebullition. It is particularly useful in the drying of the precipitates obtained in the analysis of minerals. It is well known that the same mineral analysed by different chemists, has been found to yield different proportions of the same ingredients, and that the difference of proportions of the constituent parts, in many cases, is often more apparent than real; arising entirely from the various degrees of desiccation that have been employed by different analysts, and sometimes even by the same person. This point is of such importance, and is productive of so much trouble, that every chemist who has analysed a mineral water, or crystallized and separated small quantities of deliquescent salts, will at once perceive the utility of the apparatus in this respect.

The apparatus may likewise be used as a water-bath. In that case, the conical glass vessel *b* is removed, and the inner tin vessel *e* filled with water; into this, retorts, flasks, gallipots, vials, bottles, &c. may be immersed for promoting the processes of distillation, digestion, solution, evaporation, &c.; or it may be used as a sand-bath (it being hard soldered) by filling the tin vessel with sifted sand, for performing these operations which require a higher temperature than that of boiling water.

When the instrument is required to be used as a freezing apparatus, the bottom cover *g* is to be taken off, and the cavity between the interior and exterior vessel filled with the frigorific mixture; a wetted piece of bladder is then to be tied over the opening, or the cover is put on to retain the mixture. The second frigorific material (for instance, if quicksilver is to be frozen) consisting, we will say, of muriate of lime and snow, are to be cooled by the mixture in the exterior vessel, by putting the muriate of lime into the conical glass vessel, together with the mercury contained in a thin glass tube; and surrounding the glass vessel, by filling the interior tin vessel with snow, or pulverised ice. When these materials have been cooled down to 0°, the snow and ice may be mixed together by emptying the muriate of lime into the vessel containing the snow, and stirring the mixture with a glass rod to facilitate the solution of the salt, and to produce the requisite degree of cold.

PLATE V.

Fig. 1 represents Webster's lamp-furnace, with concentric wicks. It consists of a brass rod, about 2 feet 9 inches high, screwed to a solid brass foot, loaded with lead. On this rod slide three metallic sockets, with straight arms, to which are screwed brass rings of different diameters, for supporting glass retorts, evaporating basins, flasks, crucibles, &c. Each of these rings may, by means of a thumb-screw, be set at different heights. Below these rings is a fountain-lamp, on Argand's plan, which, by means of a thumb-screw, may also be elevated or depressed, in order to communicate more or less heat to the vessel suspended over it. The superior advantage this instrument possesses consists in a second cylinder, added to that of the lamp of Argand. These cylinders are concentric; and by this ingenious contrivance, a double flame, and more than double the heat of a common Argand's lamp, may be obtained. This lamp-furnace is therefore far preferable to that of Guiton, or any other I am acquainted with.

Fig. 2 is a detonating or eudiometer tube of glass. Its bore is about half an inch, and its height about 12. It is graduated into cubic inches, and sub-divided into decimal

parts. By means of the two conductors *a a*, a quantity of gas, confined in the tube by water or mercury, may easily be inflamed by the electric spark. Hence this tube is extremely convenient for shewing the production of water, nitrous acid, or to expose a confined quantity of gas to an intense heat.

Fig. 3, an apparatus serving the same purpose may be formed by hermetically sealing a piece of platina or other wire furnished with a knob or small ball, into the end of a glass tube. With this conductor an interrupted circuit may be formed, by introducing into the tube a longer wire, one end of which terminates one-tenth of an inch from the upper one, while the other extends beyond the aperture of the tube.

Fig. 4, a graduated pneumatic, tube, divided into inch cubes, and decimal parts for measuring gases.

Fig. 5, Dr. Hope's Eudiometer. Since the printing of the preceding sheets, we have become acquainted with the following simple and elegant eudiometer invented by Dr. Hope.

It consists of a small bottle, of the capacity of 20 or 24 drachms, destined to contain the eudiometric liquid, and having a small stopper at *b*. Into the neck of the bottle a tube is accurately fitted, by grinding, which holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first filled with the liquid employed, which is best prepared by boiling a mixture of lime and sulphur with water, filtering the solution, and agitating it for some time in a bottle half filled with common air. The tube, filled with the gas under examination, (or with atmospherical air, when the quality of this compound is to be ascertained), is next put into its place; and, on inverting the instrument, the gas ascends into the bottle, where it is brought extensively into contact with the liquid, by brisk agitation. An absorption ensues; and, to supply its place, the stopper *b* is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation renewed; and these operations performed alternately, till no farther diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be appa-

rent. Its amount may be measured by a graduated scale marked on the tube.

Fig. 6, Guiton's improved still and refrigeratory 7. The body of this still, which may be made of japanned iron or copper, is nearly as broad as it is high; the bottom is concave, in order that the fire may be nearly at an equal distance from all the parts of its surface; the sides are elevated perpendicularly, in such a manner that the body of the still exhibits the form of a portion of a cylinder; and this body is covered with a vast capital, having a groove, or channel, projecting two inches at its lower part within, as shewn by the dotted line: the sides have an inclination of sixty-five degrees; because it has been ascertained that, at this degree, a drop of fluid will run along without falling again into the body of the still. The beak *c* of the capital insensibly diminishes till it comes to the worm-pipe; it is then connected with the tube *d* of the refrigeratory, which descends nearly to the bottom of the inner cylinder of the refrigeratory as exhibited by the dotted line. By this means the first portion of vapour that passes over becomes condensed, and forms a small reservoir just sufficient to cover the orifice of the tube, after which no uncondensed vapour can escape. The fluid then passes off through the spiral tube. This still is very portable, and may be placed on a chafing-dish, furnace, or on a common fire.

PLATE VI.

Fig. 1 represents a portable universal furnace, *very convenient for all chemical operations whatever, which require the assistance of heat.* This furnace is particularly useful to such amateurs of chemical science as have no access to the laboratory: for those who are familiar with practical chemistry will readily allow that a furnace capable of producing a very low and very intense heat, and calculated for all chemical operations whatever, which require the aid of heat, is one of the most requisite and most indispensable instruments of the apparatus of the laboratory: moreover the great advantages of this furnace *(which was first invented by Dr. Black, and improved by others)* above others I am acquainted with, con-

sists in consuming as little fuel as possible; in producing quickly, if required, a very intense heat; in regulating expeditiously, and at pleasure, its intensity; in applying it as directly, and as fully as possible, to the substances upon which it is intended to act; and moreover in enabling the operator to perform his operations in the closet, or in any other place, without the risk of endangering the conflagration of the surrounding objects, which were not meant to be exposed to the fire.

This portable universal furnace is made of strong wrought iron plates. It is lined with fire-bricks, bedded in fire-proof loam. Its height without the chimney *a a* is two feet. The inner diameter of the cylindrical fire-place measures ten inches. The body of the furnace is elliptical; in its upper part a circular hole is cut for receiving an iron sand-pot *b*, which may occasionally be removed and exchanged for an iron cover. In the front of the furnace there are three openings over each other, furnished with doors, and fitted with stoppers made of crucible ware. The lower opening *c*, is the ash-pit of the furnace; it is composed of two register plates, sliding backward and forwards in grooves, in order to diminish or enlarge the opening for regulating the heat, by admitting or excluding air at pleasure. In the side of the furnace a hole is cut, furnished with a stopper and door, for passing the tube through the fire-place of the furnace; an expedient very necessary for a variety of chemical processes, such as exhibiting the decomposition of water, alcohol, oils, &c. for the preparation of phosphuret of lime, for passing gases over ignited bodies, &c. In either of the two middle openings in front of the furnace, a muffle may be placed for performing the process of cupellation of gold, silver, &c, or, the neck of a retort, (placed on a stand in the body of the furnace) may be passed through it, for distillation by the naked fire: for procuring gases which require a high degree of heat, &c. &c. If the iron sand-pot *b* be removed, and a circular plate properly lined with fire-clay be placed in its room, it becomes converted into a wind-furnace; the fuel is then to be introduced through either of the openings in front. The iron cover at the top has a hole in the centre, furnished with the stopper, to enable the operator to inspect his process at

pleasure. If the iron sand-pot be placed inverted on the opening of the furnace, it forms a dome, and it then becomes a reverberating furnace. The iron pot, when filled with sand or water, placed in its proper situation, serves as a sand or water-bath, for the processes of distillation by means of glass retorts, for evaporations, sublimations, digestions, &c. Coke and charcoal are the best fuel for this furnace: this mixture burns without smoke, and gives a strong uniform and permanent heat; charcoal and common coal, or coal only, does likewise very well. The elbow of the chimney *a* may be directed into the fire-place of any apartment. The furnace is furnished with castors, and may therefore be easily moved according to the convenience of the operator.

Fig. 2, Dr. Gruber's conducting tube. It consists of two metal tubes joined to a metal box consisting of two pieces, sliding in and over each other, made air-tight by grinding. The one end of the tube (in the drawing) is joined to the retort placed in the furnace, the extremity of the other tube is extended into the pneumatic trough. The tubes may be elongated by additional pieces to any length required.

Fig. 3, a bell glass, having a neck furnished with a brass cap, into which is screwed a stop-cock for transferring gases into flasks, bladders, &c.; *a* is a small brass connecting piece, with two female screws, by means of which another stop-cock, fixed to a flask or bladder, may be connected with the stop-cock of the receiver.

Fig. 4, a flask for weighing gases. Its orifice is furnished with a brass cap and stop-cock. The flask is connected with a bell-glass, in the manner stated before. If this flask has been previously exhausted by means of an exhausting syringe, and a communication be then made with the bell-glass by opening both cocks, the gas contained in the bell-glass may be transferred into the flask, by pressing down the bell-glass into the water of the pneumatic trough; the gas will be forced up into the flask, the cocks being then shut, the flask may be removed, and its weight ascertained by means of a delicate balance. The difference between the weights of the flask when exhausted, and when filled, gives the weight of the gas in the flask, which may, by this method, be compared to common air, &c.

Fig. 5, a perspective view of the pneumatic cistern, of which a description has been given already, page 178, vol. i. See pneumatic apparatus.

Fig. 6, represents a bladder connected to a stop-cock. To fill the bladder with gas, squeeze out the air, adapt it to the receiver, fig, 3, instead of the flask, fig. 4, and proceed as before directed.

Fig. 7, a sliding stand for holding receivers.

Fig. 8, a blow-pipe furnished with a stop-cock, which may be joined to the bladder, fig. 6. The bladder being filled with oxygen gas, a very intense heat may be produced by directing the stream of it on a piece of ignited charcoal as shown fig. 8, and the most refractory substance may thus conveniently be exposed to the action of an intense heat.

Fig. 9, a metal tobacco-pipe and stop-cock, which may also be connected with the bladder, for throwing up soap bubbles filled with hydrogen, or other gases.

Fig. 10, an improved self-registering thermometer. Many contrivances have been proposed and adopted for registering all the stations of the thermometer and barometer, by means of a float or other equivalent instrument carrying a pencil, which marks its situation on a surface gradually moved along by means of a clock. These, of which meteorologists know the value, are nevertheless expensive, and require a degree of care and management sufficient to render simpler contrivances acceptable. Mr. James Six communicated, about 25 years ago, to the Royal Society a thermometer in which two small indicating pieces were driven by the fluid in the tubes to stations where they stuck, and remained after the change of temperature, and showed the highest and lowest degrees that had occurred since the last placing of them in contact with it. As this instrument is sufficiently known, and I am now to advert to a simpler contrivance, we shall dismiss this subject and advert to this last.

In Mr. Six's complicated thermometer the tubes were vertical, and the indexes stuck in the glass by their spring; besides which, a small piece of steel wire being exposed to alcohol, was at length oxydated and set fast. The other contrivance, which I had the honour to exhibit 8 years ago at the meetings held at the house of the

President of the Royal Society, and of which I gave a description in Nicholson's Journal, Nov. 1805, consists simply in two thermometers, one mercurial and the other of alcohol, having their stems horizontal; and the former has for its index a small bit of magnetical steel wire, and the latter filled with a minute thread of glass, having its two ends formed into small knobs by fusion in the flame of a candle.

The magnetical piece of wire lies in the vacant space of the mercurial thermometer, and is pushed forward by that mercury whenever the temperature rises and pushes the fluid against it: but when the temperature falls and the fluid retires, this index is left behind, and consequently shews the maximum. The other index, or piece of enamel, lies in the tube of the spirit thermometer immersed in the alcohol, and when the spirit retires by depression of temperature, the index is carried along with it in apparent contact with its interior surface: but on an increase of temperature the spirit goes forward and leaves the index behind, which therefore shews the minimum of temperature since it was set. As these indexes merely lie in the tubes, their resistance to motion is altogether inconsiderable. The steel index is brought to the mercury by applying a small magnet on the outside of the tube, and the other is duly placed at the end of the column of alcohol by inclining the instrument.

The theory of the action of these thermometers Mr. Nicholson has explained (see the Journal before quoted) thus:

"When the surface of the column of spirit is viewed by a magnifier, it is seen to have the form of a concave hemisphere, which shows that the liquid is attracted by the glass. The glass in that place is consequently attracted in the opposite direction by a force equal to that which is so employed in maintaining that concave figure; and if it were at liberty to move, it would be drawn back till the flat surface was restored. Let us suppose a small stick or piece of glass to be loose within the tube, and to protrude into the vacant space beyond the surface of the alcohol. The fluid will be attracted also by this glass, and form a concave between its surface and that of the bore of the tube. But the small interior piece being quite

at liberty to move, will be drawn towards the spirit so long as any attractive force posseses any activity; that is, so long as any additional fluid hangs round the glass, or, in other words, until the end of the stick of glass is even with the surface. Whence it is seen that the small piece of glass will be resisted, in any action that may tend to protrude it beyond the surface of the fluid; and, if this resistance be greater than the force required to slide it along in the tube (as in fact it is) the piece must be slided along as the alcohol contracts, so as always to keep the piece within the fluid. And this fact is accordingly observed to take place."

Fig. 11 and 12, air-thermometers or manometers. The air-thermometer represented with its bulb downwards and supported by a stand, has been described already, vol. i. p. 97. The other manometer differs from the former, by being constructed of a straight tube, one extremity of which is secured air-tight into a bottle containing some coloured fluid; the other open extremity being in contact with the atmosphere. On applying the hand to the bottle, the air confined in it expands, and consequently causes the fluid to rise in the tube; a reduction of temperature produces the contrary effect.

Fig. 13 is a deflagrating ladle for the combustion of various substances in oxygen gas.

Fig. 14, an evaporating basin of biscuit ware for evaporating fluids by the lamp or sand-bath. The operator should be provided with basins of this kind in sizes.

Fig 15, an apparatus for separating deliquescent salts from such as do not absorb moisture enough to become fluid, when exposed to the atmosphere. *a* denotes a small circular stand, holding a funnel which has a very shallow area, and a narrow tube *c*, terminating in a samll bottle *d*, to collect the deliquescent salt, which has been occasioned by exposing the saline mass over the area of the funnel, in the atmosphere.

Fig. 16, a bottle for readily ascertaining specific gravities of fluids; it consists of a bottle with a slender neck, and ground stopper, having a mark made with a diamond in the neck of it. When this bottle is filled up to the mark with distilled water of a given temperature, it should hold exactly 1000, 2000, or any even number of grains. The quantity which it is found to contain of any other

fluid of the same temperature denotes the specific gravity of the latter fluid. For example, if it holds 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the sulphuric acid is to that of water as 1850 to 1000.

Fig. 17, 18, 19, porcelain or earthen-ware tubes for the decomposition of water, alcohol, oil, &c. &c. See portable furnace, fig. 1. pl. 6.

Fig. 20, a graduated eudiometer, described already. See eudiometry.

Fig. 21, adopters or conical tubes of glass or earthen-ware, fitting one into another: they are used for occasionally elongating the necks of retorts, &c. to connect them together with the receiver, at any required distance. They are sometimes made to swell out in the middle, as represented fig. 22.

PLATE VII.

Fig. 1 represents Pepy's distillatory apparatus for impregnating fluids with gases, &c. A is a tubulated retort, joined to a tubulated receiver *b*, into which is fitted by grinding the pear-shaped vessel *c*, furnished with a valve, constructed by placing a plano-convex lens upon the mouth of a small tube, accurately fitted by grinding, and inserted into the lower aperture of the pear-shaped vessel *c*, and similar to the valve in the well known apparatus of Nooth, but with more water way. From this it is obvious that the gas disengaged from the retort, and which is not absorbed by the fluid contained in the receiver *b*, will by its upward pressure raise the valve, and pass into the pear-shaped vessel *c*, without allowing the fluid contained in it to return into the receiver *b*, even when a partial *vacuum* takes place. The gas which is not absorbed passes into the first three-necked bottle *d*, and if any part should escape absorption by the fluid in that vessel, it passes into the second bottle *e*, or may lastly be conducted into the pneumatic trough by means of the tube *f*.

Fig. 2 represents Smith's pyrometer, described page 98, vol. i.

Fig. 3 a gas bottle with Sigmoid's tube for disengaging gases. When a permanently elastic fluid is generated within the body of the gas bottle, it escapes by the ex-

tremity of the recurved tube, and may be collected by introducing it under the jar filled with water or mercury in the pneumatic cistern. This simple apparatus can only be used conveniently when the production of the gas is not rapid, or acquires the application of slight heat.

Fig. 4, a pneumatic cistern of japanned iron, for the use of the table: it is very convenient for experiments in the small way. *a* denotes a bell-glass, standing on the shelf of the cistern to receive the gas.

Fig. 5, a chemical lamp on Argand's plan.

Fig. 6, a vessel for boiling inflammable fluids. The vessel should not be filled too full, and the long spout should be placed so as to be heated as little as possible. When the fluid begins to swell and boil up both from the great increase of the surface, and from part of it running up the cooler spout, the ebullition will be checked, and all danger of running over be prevented. The short spout is convenient for pouring out.

Fig. 7, a conical glass, the inside of which terminates in an oval bottom, for putting in a small piece of a mineral, to try the action of acids upon it, having a glass rod to stir it. *a* is a piece of plate glass to cover the glass in order to exclude dust.

Fig. 8, a precipitating glass for collecting small quantities of precipitates.

Fig. 9, a long conical glass for filtrating or precipitating, &c. *a* is a glass funnel with four or six small solid glass rods, bent on one end, *c*, hanging round the inside of the funnel, to prevent the filtering paper sticking close to the side of the funnel which is placed in the glass.

Fig. 10, an apparatus for easily ascertaining the quantity of carbonic acid disengaged from any substance by the action of an acid: it consists of a bottle closed by a cork or stopper, into which is fixed a spiral tube terminating into a capillary opening. To use this apparatus, ascertain first what quantity of muriatic or nitric acid is required to saturate a given quantity of the substance, intended to be submitted to the experiment. Having done this, put the quantity of acid or rather more into the bottle, and weigh the whole accurately; then add to it the substance, the quantity of carbonic acid of which is to be ascertained; cork the bottle as expeditiously as possible,

and suffer the carbonic acid to escape. When the effervescence has completely ceased, let the whole apparatus be again weighed, and the loss of weight will indicate the quantity of carbonic acid contained in the substance, with tolerable accuracy. The spiral tube prevents the carbonic acid from carrying off moisture.

Fig. 11, an alembic for distillations.

Fig. 12, a cast-iron retort which requires no luting, for obtaining oxygen gas, by the culinary fire.

Fig. 13, an improved conducting tube to fit the iron retort, similar to that described fig. 2, pl. vi.

LUTES.

Lutes also form a necessary part of chemical apparatus. They are compositions of various substances, intended,

a. To close the joinings of apparatus.
b. To coat glass and other vessels.
c. To line furnaces.

Lutes of the first description are commonly employed to confine elastic vapours. They should therefore possess the following properties:

a. Compactness.
b. The power of resisting acrid vapours.
c. The power of resisting a certain intensity of heat.
d. Facility of removal after the operation.

Viscid substances, as flour, starch, and gum, possess the first and last properties in a sufficient degree; they are therefore employed when the heat is moderate, and the vapour not corrosive. They are mixed with water, and spread upon slips of paper or linen, which are wrapped round the joinings of the vessels, and, if necessary, secured with thread.

Slips of bladder macerated in water, and applied with the inside next the vessels, are employed in the same circumstances; but from their great contraction on drying, they are apt to break weak vessels.

A paste formed of almond or linseed meal and water, or mucilage, forms a very close and plastic lute, which is easily removed.

Quicklime reduced to powder and well incorporated with a sixth part of muriate of soda, or with white of egg diluted with water, applied on slips of linen, dries easily, and becomes very hard. It is used for the distillation of the concentrated acids; but for this purpose burnt gypsum and water answers very well. Both these lutes must be used as soon as they are prepared, as they harden very quickly.

Chalk and oil, or glazier's putty, is a very compact lute. As it becomes so hard as not to be easily removed, it is principally used for luting tubes into vessels for pneumatic purposes.

A paste of powdered tobacco pipe-clay and drying oil, or, what is still better, amber varnish, is very close, adhesive, and plastic, and is easily removed; but as it softens with heat, it must be secured by slips of linen and thread, and will not adhere to the vessels unless they be perfectly dry.

The same clay beat up with as much sand as it will bear, without loosing its tenacity, with the addition of cut tow and a sufficient quantity of water, furnishes a very good lute, which has the advantage of resisting a considerable heat, and it is applicable where the fat lute would be melted or destroyed.

Clay and sand, in the proportion of one to four, form an excellent lute, capable of resisting very high temperatures, and the greatest number of corrosive substances.

Eight parts of yellow wax melted with one of oil of turpentine, with or without the addition of some resinous substances, according to the degree of pliability and consistence required, form a very close and compact lute, through which the most subtile corrosive vapours will not escape. But it is softened and liquefied by heat, therefore cannot be used for purposes where high temperatures are required.

The lute employed for the coating of glass vessels, with the intention of making them stronger and capable of resisting violent heats, without softening, consists of four parts of sand and one of clay, made into a very thin mass, and applied in successive layers, taking care that each coat be perfectly dry before another be laid on.

In every instance where a lute is applied it is absolutely necessary to allow it to dry before the process is begun;

and even the fat lute, by the exposure to the air during a few days after its application, is much improved in its quality. Lutes composed of clay and sand are perfectly useless, except they be permitted to be perfectly dry. In applying a lute, the part immediately over the junction of the vessel should swell outwards and its diameter should be gradually diminished at each side.

The juncture of vessels which are to be luted to each other must previously be accurately and firmly fitted, by introducing between them, when necessary, short bits of wood or cork, or if the disproportion be very great, by means of a cork fitted to the one vessel, having a circular hole bored through it, through which the neck of the other vessel or tube passes.

After being thus fitted, the lute is rolled and worked betweed the fingers till it be softened, and is then formed into small cylinders, which are successively applied to the junctures, taking care that each piece be made to adhere firmly and perfectly close in every part before another is put on. Lastly, the whole is secured by the slips of linen or bladder.

In many cases to permit the escape of elastic vapours, a small hole is made through the lute with a pin, or the lute is perforated by a small quill, fitted with a stopper. This, however, is seldom necessary.

FUEL AND APPLICATION OF HEAT.

As caloric is an agent of the most extensive utility in the chemical operations of chemistry, it is necessary that we should be acquainted with the means of employing it in the most economical and efficient manner.

The rays of the sun are used to accelerate spontaneous evaporation ; the only attentions necessary are to expose as large a surface of the fluid as possible.

The combustion of different substances is a much more powerful and certain source of heat. Alcohol, oil, tallow, wood, turf, coal, charcoal, and coke, are all occasionally employed.

Alcohol, oil, and melted tallow, are burnt in lamps of various constructions. These afford a very uniform, though not very high temperature. Alcohol has the great advantage of burning without smoke. But oil burnt upon

a cylindrical wick, so contrived that the air has free access both to the outside and to the inside of the cylinder, as in Argand's lamp, may be made to produce a considerable temperature of great uniformity and without the inconvenience of smoke.

Wood, turf, coal, charcoal and coke, are burnt in grates and furnaces. Wood has the advantage of kindling readily, but affords a very unsteady temperature, is inconvenient from its flame, smoke, and soot, and requires much attention. The heavy and dense woods give the greatest heat, burn longest, and leave a dense charcoal.

Dry turf gives a permanent heat, and does not require so much attention as wood; but its smoke is copious and penetrating, and the empyreumatic smell which it imparts to every thing it comes in contact with adheres to them with great obstinacy. The heavy turf of marshes is preferable to the light superficial turf.

Coal is the fuel most commonly used in the laboratory. Its heat is considerable and sufficiently permanent, but it produces much flame and smoke.

Charcoal, especially of the dense woods, is a very convenient and excellent fuel. It burns without flame or smoke, and gives a strong, uniform, and permanent heat, which may be easily regulated, especially when it is not in too large pieces, and is a little damp.

Coke, or charred coal, possesses similar properties to charcoal. It is less easily kindled, but is capable of producing a higher temperature. *The best fuel for general purposes of the laboratory, however, is coke and charcoal mixt together; two or three parts of the former to one of the latter*, broken into pieces of the size of a walnut.

APPENDIX TO VOL. II.

PAGE 7.—NO. 31.

Count Mousin Pouschkin's method of procuring malleable platina, is in substance thus: Wash the crude platina, to free it from impurities: digest it in dilute marine acid: wash it well: dissolve it in nitro-muriatic acid: precipitate by sal ammoniac: wash it, but not in much water: dry it: fold up the orange coloured precipitate in paper, and press it into a crucible: cover it: expose it to heat till it becomes a spongy metallic mass: take it out when cold, and boil it in dilute marine acid for half an hour: wash it: expose it again for half an hour to the heat of full ignition: let it cool, and amalgamate it with mercury, in the proportion of mercury two parts, platina three parts, by weight: continue to add mercury and platina in about that proportion till your whole quantity is amalgamated: mould it in bars or plates of half an inch thick, by pressing it with a screw into wooden moulds, which may be burnt away: expel the mercury by strong ignition urged with a bellows under a muffle: so soon as the bars become hard, expose them repeatedly, but gently, to the hammer, to be forged; they may then be either forged strongly or laminated between rollers.

Another way: proceed to procure the orange coloured precipitate: wrap it in paper with a small quantity of lamp black: expose it to strong ignition in a covered crucible until it becomes a spongy metallic mass: while in strong ignition press it down with force, at first gently and cautiously applied, for fear of breaking the crucible, till the mass becomes somewhat compact: then take it out while hot, and hammer it gently: repeat this till it is capable of bearing the hammer strong enough to forge it.

Tilloch says, that if the edulcorated precipitate by sal-ammoniac, be placed between plates of platina, secured, and strongly heated, it will unite to the malleable platina, and may be forged with it.

Dr. Bollman of Philadelphia forges platina, and manufactures it into any form, but by what method I know not.

PAGE 31.—NO. 32.

Professor Silliman has improved the process of procuring fulminating silver. To an ounce of alcohol and as much nitric acid, add 100 grains pulverized lunar caustic (nitr. silver). Apply heat, if necessary to excite an action between them, which must be removed so soon as they begin to act on each other. When a thick white precipitate ap-

pears, throw cold water in to check the action. Wash the precipitate; filter it: dry it gently and carefully in the filter. A grain or two on the point of a knife will explode over a candle.

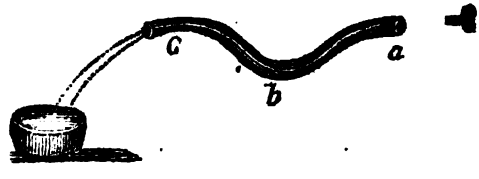
PAGE 224.—NO. 33.

Of the alkaline and earthy metalloids. The alkalies and alkaline earths had frequently been suspected as metallic bodies, but no one had found out any method of bringing this supposition to the test of experiment, till Mr. Davy (now, very deservedly, sir Humphrey Davy) in the beginning of October, 1807, during a course of experiments on the chemical agency of Galvanic electricity, decomposed the alkali of potass. When boiling water is poured upon common pearl-ash, mixed with once and a half its weight of good fresh-burnt lime, and well stirred, the carbonic acid of the pearl-ash unites with the lime, and the alkali is held in solution, in a state, until that time, usually deemed pure. The clear solution should be evaporated to dryness, when upon being treated with alcohol of specific gravity .825, the pure alkali will be dissolved, and the neutral salts that contaminate it, will be left behind. If this solution of alkali in alcohol be distilled, the alcohol can be recovered clear, and the alkali remaining can be fused in a silver crucible until it flows like oil, is of a dull red heat, and begins to evaporate in substance. In this state, it must be poured out on a hot polished metal plate, broken *very quickly into* small pieces while hot, and put into a wide mouthed vial or bottle also previously made hot, so as not to crack by contact with the hot alkali, and then corked up tightly for use.

I have procured the metalloid potassium, without being at the trouble of making an alcoholic solution, by evaporating the liquor from the pearl-ash and lime in a brass basin silvered, and fusing the alkali to a red heat in a polished iron crucible. In this state, the alkali still retains between 13 and 14 per cent. of water, and the hydrat of potash itself will evaporate, before the water can be separated by heat alone.

If a thin piece of potass thus fused, be placed between two discs of platina, connected with the extremities of a voltaic apparatus of 200 double plates six inches square, it will soon undergo fusion: oxygen will separate at the positive surface, and small metallic globules will appear at the negative surface: these are the *metal*, or rather, perhaps, in the present state of our knowledge, the *metalloid* POTASSIUM.

Gay Lussac and Thenard afterward, in 1808, procured potassium, by decomposing pure potass by distilling it over, and making it pass through clean iron filings contained in a gun barrel, and exposed to a white heat. The gun barrel is bent to go into the furnace, thus,



The iron filings or turnings are contained in the bent part, and the two ends come out at apertures in the sides of the furnace. The alkali is put in at *a*, and pushed down on the white hot iron filings, where it is decomposed; the oxygen of the water unites to the iron. The hydrogen escapes along a tube represented by the dotted line, the end of which is immersed in a basin of olive oil. The potassium is distilled over the iron filings, and lodges in the part of the gun barrel *c*, which is kept as cool as possible: but great care is taken, that no moisture can get through the luting of the tube. It is also highly necessary, previously to examine the soundness of the gun barrel; and to choose a well made and thick one. I think a *white* heat is necessary. A tube about a foot long may be joined to the end of the gun barrel, *c*, and the potassium may be made to collect therein; as a greater extent of cooled iron can thus be obtained.

Dr. Woodhouse procured it (Phil. Trans. 1809) by decomposing potash by charcoal; but he was not aware of the metallic nature or properties of the combustible substance he found in the crucible. Curadeau procured potassium also in 1808, by igniting potash with charcoal. These experiments bear upon the theory of Homberg's pyrophorus. Potassium, thus obtained, is lighter than water, its specific gravity being between .8 and .9. It is solid at common temperatures. It is soft and can be moulded by the fingers. It cuts like butter. It is of a silvery white and perfectly metallic appearance. It decomposes water with such rapidity, that the hydrogen of the water is set on fire, while the oxygen combines with the potassium, and again forms potass. When thrown into water, it burns with a rose coloured flame, and the potassium whirls round on the surface of the water with a gyratory motion. The water contains potash. It is decomposed in alcohol, in olive oil, in linseed oil, in oil of turpentine, in bituminous oil, even in common petroleum; it can be preserved only in the very thin pure kind of petroleum, called naptha, brought, I believe, from Persia. It fuses at 150° Fahrenheit, and rises in vapour, in a heat a little below redness. It inflames when gently heated in the air, burns with a reddish flame, and throws off alkaline fumes, owing to its decomposing the moisture of the atmosphere and uniting with oxygen. It burns spontaneously, with great vividness, in chlorine gas. It is a conductor of electricity. It amalgamates with mercury, forming a mass, with well characterized appearances of a metallic alloy. It combines with oxygen in various proportions, and when gently burnt in common air, each grain appears to take up 1.7 cubic inch of oxygen, forming an orange coloured fusible substance. Gay Lussac and Thenard first suggested, that this was the per-oxyd of potassium; an opinion that Davy adopts. When this substance is strongly heated upon platina, it gives out oxygen, and a gray coloured substance, with a vitreous fracture, remains: this last is pure potass; the substance commonly called potass, is a hydrat of potass.

Potassium combines with sulphur and phosphorus, producing light and heat. It combines feebly with charcoal. It seems to be the proper test or re-agent for discovering the presence of oxygen.

Sodium, is a metalloid procured from the alkali of soda in the same manner as potassium from the alkali of potass. Davy discovered it in 1807. It is white as silver; possesses great metallic lustre; is a conductor of electricity; fuses at 200 Fahrenheit, rises in vapour in a red heat; specific gravity between .9 and 1; effervesces violently in water, but does not inflame; swims on the surface, is gradually decomposed, and the water becomes a solution of soda: it acts upon other bodies in a manner very like potassium. It forms two combinations with oxygen,

the common soda heretofore deemed pure, and the orange or per-oxyd. Pure soda may be obtained by burning sodium in a quantity of air no greater than necessary to oxygenate it into an alkali: the sodium must be in excess, and the heat strong; the colour is gray; the fracture vitreous: it seizes violently on water, and becomes the common hydrat of soda. Sodium burns vividly in chlorine gas. It combines with sulphur and phosphorus, and feebly with charcoal.

Ammonium. In the course of Davy's experiments on the alkalies, he submitted ammonia, liquid, and also in the state of an ammoniacal salt, to galvanic action, in contact with mercury. The mercury was increased in volume, but the specific gravity was greatly reduced, and it became nearly solid without losing its metallic lustre. A similar effect was produced when potassium was so treated with ammonia. These experiments of Davy were seemingly confirmed by Berzelius and Pontin, who found that the ammoniacal amalgam dropt in water evolved hydrogen; and mercury and ammonia were reproduced. Davy also, as they did, found, that when the amalgam was confined in air, a quantity of oxygen disappeared equal to about 1-7th or 1-8th of the ammonia. But later experiments of Gay Lussac and Thenard, of Dr. Henry, and of Davy himself, render the existence of oxygen in ammonia extremely doubtful; nor can any character sufficiently distinct be yet given to the amalgam with ammonia. Davy, for reasons grounded, I presume, on these experiments, has not included ammonium among the metals, in his late Elements of Chemical Philosophy.

Barium. Dissolve carbonat of barytes in nitric acid: evaporate: decompose the nitrat by strong heat: a fawn-coloured powder remains, which, according to Davy, is oxyd of barium. This oxyd, made into a paste with water, is exposed upon a plate of platina to galvanic action, as in case of the alkalies. A cavity is made in the paste, to hold a globule of mercury; which is rendered negative, while the platina is rendered positive, by means of a voltaic battery of 100 double plates. In a short time an amalgam is formed. This amalgam, put into a tube of *common* (*not flint*) glass, free from lead, and filled with the vapour of naptha, is distilled. The mercury is driven over, and the barium remains; a solid metalline substance, of difficult fusibility, which has not been procured in sufficient quantity for accurate examination. It is metallic, but with lustre inferior to cast iron; its colour a dull gray; *it* effervesces with water, which then becomes a solution of barytes; *it* sinks in sulphuric acid; it alloys with iron; it combines, according to Davy, with 10.3 of oxygen, to form barytes.

Strontium, may be procured in the same manner, and appears to have similar properties.

Calcium, from lime, and *magnesium*, from magnesia, have also been thus produced.

No metalloid appears as yet to have been decisively produced from any of the other earths.

I have termed these substances *metalloids*, because I think the supposition of their being *metals*, is not quite clear of doubt. In favour of their being metals, it may be urged, that

They have the well known metallic lustre.

They amalgamate with mercury, and the amalgam is metallic.

They combine with oxygen in various proportions.

They conduct electricity like metallic substances.

They decompose water; as most metals do while dissolving in acids.

They unite to acids, forming neutral combinations. It is not yet ascer-

tained whether the proportion of acid necessary to neutralize them, is as the oxygen combined with them.

On the other hand, it may be urged, that,

The great levity of potassium is in direct opposition to one of the most known characteristics of metallic bodies, viz. their superior density.

The addition of oxygen to a substance in all other cases, increases the specific gravity of the substance, but in the present case it is the reverse.

All the processes for forming the metalloids, tend strongly to the suspicion that the oxygen is separated from the alkali, but hydrogen remains; and that they are alkaline hydrogurets. Hence they may be merely substances exhibiting alkali free from oxygen, which, when added to them, reconverts them into alkalies of the common character.

Several substances have the metallic lustre, which are clearly not metals, as the recently dug cubic pyrites, the marcasites, &c.

I do not think their classification is as yet sufficiently determined, and therefore I have agreed to the denomination of metalloids, rather than metals.

PAGE 274.—NO. 34.

Professor Davy has given the following method of making phosphorous acid, by distilling phosphorus through corrosive sublimate in powder in a glass tube.

PAGE 292.—NO. 35.

The chromic acid may be obtained from the chromate of iron by fusing the latter with its weight of nitre; lixiviating, crystallizing repeatedly, to get rid of the iron, then saturating the alkali with nitric acid, and re-crystallizing: but this also must be repeatedly done; nor is it easy to get the ruby crystals of chromic acid, free from nitrate of potash, and from the green oxyd of chrome.

PAGE 300.—NO. 36.

Tartar, when crude, is known in commerce by the name of *argal*, or *argol*. It is the salt that crystallizes on the insides of wine casks. The tartar of red wine is red argol, the tartar of white wine is white argol. When dissolved, filtered, and crystallized, it is the common *cream of tartar* of the shops. It gives the name to salt of tartar, for when crude tartar wrapped up in paper, is exposed to strong heat in a crucible, the acid is decomposed, and the alkali of potash is left behind. This, when dissolved, filtered, and slowly dried, is the *salt of tartar* of the shops. The acid of tartar (as it is found in common tartar) is essential to educe the scarlet colour from cochineal upon woollen. A salt of lemons, under the name of the acid of lemons, is sold, which I suspect to be the pure acid of tartar, flavoured either with lemon juice, or the essential oil of lemons.

PAGE 326.—NO. 37.

A new mode of analysing vegetable substances, so as to determine the proportions of their ultimate elements, has been introduced by Gay Lussac and Thenard. Being composed in general, either entirely, or nearly so, of carbon, hydrogen, and oxygen, the easiest mode of analysis is to convert the vegetable matter by oxygenation into water and carbonic acid. This had been attempted by Lavoisier, with regard to some substances, by combustion; but this mode could only be applied to those vegetable substances which are highly inflammable; while the method of Gay Lussac and Thenard can be applied to every species of vegetable matter. It consists in burning the substances operated on, by means of the hyper-oxymuriate of potash, in an apparatus in which all the products of the combustion may be collected. A certain *weight of* the vegetable product which is to be analysed, is intimately mixed with fused hyper-oxymuriate of potash, the composition of which has been previously determined by analysis, both having been previously dried at the heat of boiling water, and the proportion of hyper-oxymuriate being used, which may be found by preliminary trials necessary to render the combustion complete. The mixture is made into small balls with water, and these are again brought to dryness by exposure to the heat of boiling water. They are introduced successively into the apparatus by means of a tube with a stop cock, having a cavity into which they are received, and to which heat is applied so as to excite the combustion. The gas produced, is collected over mercury: the quantity of carbonic acid it contains, is estimated by absorption by solution *of potash*. An excess of oxygen generally disengaged from the decomposition of the salt, will be found in the residual gas: any nitrogen gas mixed with it will be discovered by removing the oxygen by eudiometrical process: and if any carburetted or oxy-carburetted hydrogen has been disengaged, it may be discovered by exploding the gas containing the excess of oxygen, with a given quantity of pure hydrogen gas. This will be consumed; and if any carburetted hydrogen gas be present, it will likewise burn during the detonation, and the diminution of volume after the combustion, will shew the quantity of this. Thus are obtained all the facts whence the proportions of the elements of the vegetable matter may be determined. The quantity of oxygen consumed, the quantity of carbonic acid formed, which, by comparison with the weight of the *substance* analysed, gives the quantity of water produced; account being also taken of any nitrogen evolved, or any carburetted hydrogen formed; and, lastly, if any fixed substance be afforded, it will remain mixed with the residual muriate of potash, and its nature and quantity may be determined. Or this may be done by the incineration of the vegetable matter, and its weight allowed for in the analysis.

Some important results have been established by the analysis executed in this mode. Gay Lussac and Thenard have found, that in a number of vegetable substances, the proportions of the oxygen and hydrogen they contain, are exactly those that form water, to which is added a certain proportion of carbon. So that this proportion of carbon, with a certain weight of water, would give the proportions of the elements of those substances. There are others in which the oxygen is present in a larger proportion to the hydrogen, than that which forms water; and in a third class there is an excess of hydrogen. From these facts they have drawn the following general conclusions: 1st. A vegetable substance is always *acid*, when the oxygen in it is to the hydrogen in a larger proportion than that in water: 2dly. A vegetable substance is always resinous or oily.

when the oxygen in it is to the hydrogen, in a less proportion than that which forms water: 3dly. A vegetable substance is neither acid nor resinous, when the hydrogen and oxygen in it are in the same proportion as that constituting water. Sugar, gum, starch, and the ligneous fibre, are of this class. The following table gives the result by this method."
(*Murray's Supp. to Ed. 2d*, 136.)

Substances analysed.	Carbon contained therein.	Oxygen contained therein.	Hydrogen contained therein.	Supposing the oxygen and hydrogen in the state of water in the substance.		
				Carbon.	Water.	Oxygen in excess.
Sugar.	42.47	50.63	6.90	42.47	57.33	..
Gum arabic.	42.23	50.84	6.93	42.23	57.77	..
Fecula.	43.55	49.68	6.77	43.55	56.45	..
Sugar of milk.	38.825	53.834	7.341	38.825	61.175	..
Oak wood.	52.53	41.78	5.69	52.53	47.47	..
Beech wood.	51.45	42.73	5.82	51.45	48.55	..
Mucous acid.	33.69	62.67	3.62	33.69	30.16	36.15
Oxalic acid.	26.57	70.69	2.74	33.57	22.87	50.56
Tartaric acid.	24.05	69 32	6.63	24.05	55.24	20.71
Citric acid.	33.81	59.86	6.33	33.81	52.75	13.44
Acetic acid.	50.22	44.15	5.63	50.22	46.91	2.87
Common resin.	75.94	13.34	10 72	75.94	15.16	8.90
Copal.	76.81	10.61	12 58	76 81	12.05	11.14
Wax.	81.79	5 54	12.67	81.79	6 30	11.91
Olive oil.	77.21	9.43	13.36	77.21	10.71	12.08

PAGE 341.—NO. 38.

Gay Lussac and Thenard have applied the oxygenating power of oxy-muriate of potash to the analysis of animal, as well as that of vegetable matter. Greater precaution, however, is necessary in its application to animal substances; for, from the nitrogen they contain, if an excess of oxy-muriate be employed, a portion of nitrous acid is formed, which leads into error. This is best obviated by avoiding an excess of the oxy-muriate, but employing as much as may be found by preliminary trials sufficient, by yielding oxygen to the carbon of the animal matter, to convert it, when heat is applied, into carbonic acid or carbonic oxyd; and by thus subverting the combination of the elements, allow the hydrogen and nitrogen to pass into the gaseous state. The whole being thus converted into elastic products, these are more easily submitted to further analysis. By this method they have analysed the four most important animal matters, fibrin, albumen, gelatin, and caseous matter. In all of them they found an excess of hydrogen above that proportion,

which, with oxygen, forms water: and this excess of hydrogen, compared with the nitrogen they contain, was not far from the proportion in which these elements form ammonia. Under this point of view, these substances may be considered as composed of carbon, a certain quantity of hydrogen and oxygen, in the proportion which forms water, and a certain quantity of nitrogen and hydrogen, in the proportion which forms ammonia. By analogy from the law, which, according to these chemists, exists with regard to vegetable matter, it may be inferred, that in the animal acids there is an excess of oxygen above these proportions, and in the animal fats an excess of hydrogen; so that animal may, like vegetable matter, be classed under three divisions with regard to the quantities of hydrogen, oxygen, and nitrogen, which they contain. (Recherches physico-chimiques, tom. 2. p. 324, 337.) The following table exhibits the results of their analysis." (*Murray*, *H.* 139.)

Substances analysed.	Charcoal contained therein.	Oxygen contained therein.	Hydrogen contained therein.	Nitrogen contained therein.	Supposing the oxygen and hydrogen in the state of water, and the nitrogen in the state of ammonia.			
					Carbon.	Water.	Ammonia.	Nitrogen.
Fibrin.	53.360	19.865	7.621	19.384	53.360	22.369	23.463	+0.808
Albumen.	52 883	23.872	7.540	15.705	52.383	27.127	23.182	—3.191
Cheese.	59.781	11.409	7.429	21.381	59.781	12.964	31.778	—4 623
Gelatin.	47.881	27.207	7.914	16.998	47.881	30 917	22.743	—1.541

The plus and minus signs, in the last column of the preceding table, indicate an excess or deficiency of nitrogen.

The following substances, not distinctly noticed by Accum, are found in the parts of animals:

Gelatin. Albumen. Mucus. Fibrin Urea. Saccharine matter. Oil. Resin Sulphur. Phosphorus. Acids. Alkalies. Earths. Metals.

Dr. Bostock has lately made it dubious whether there be gelatin in the blood. Of gelatin, tannin is the precipitate. Gelatin is not affected by heat or corrosive sublimate. Albumen is coagulated by heat; by corrosive sublimate. When the albumen was thus separated, tannin shewed no indication of gelatin. Acetite of lead, the proper precipitant of mucus, afforded a copious precipitate.

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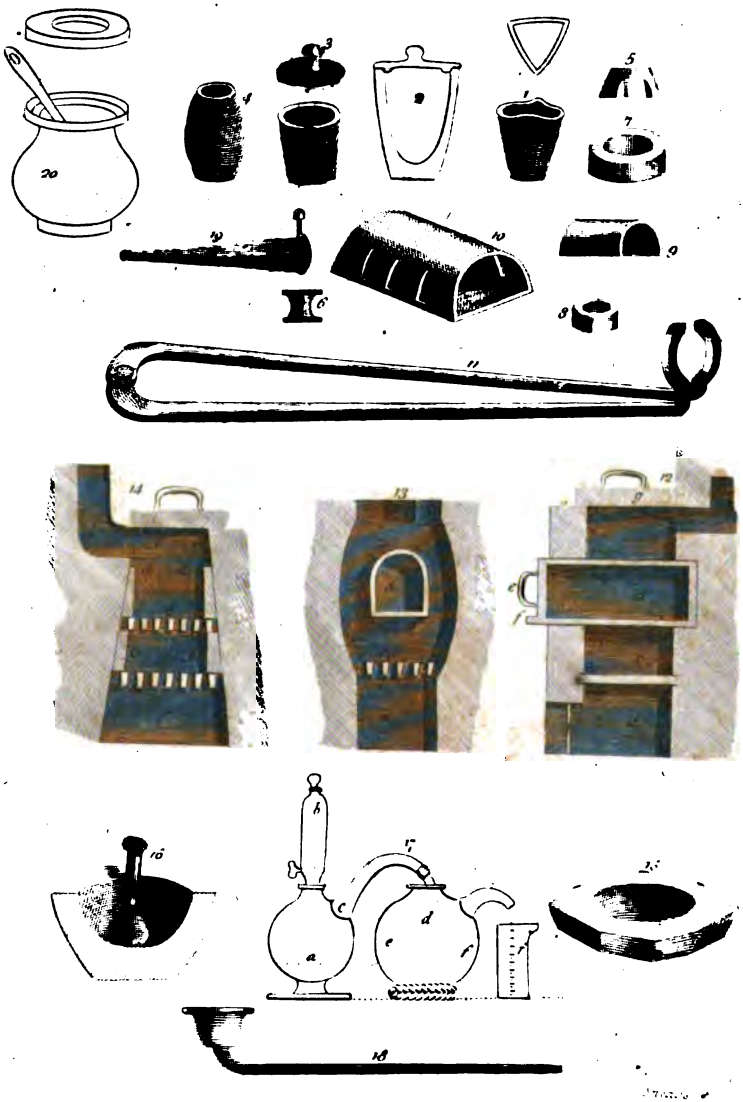
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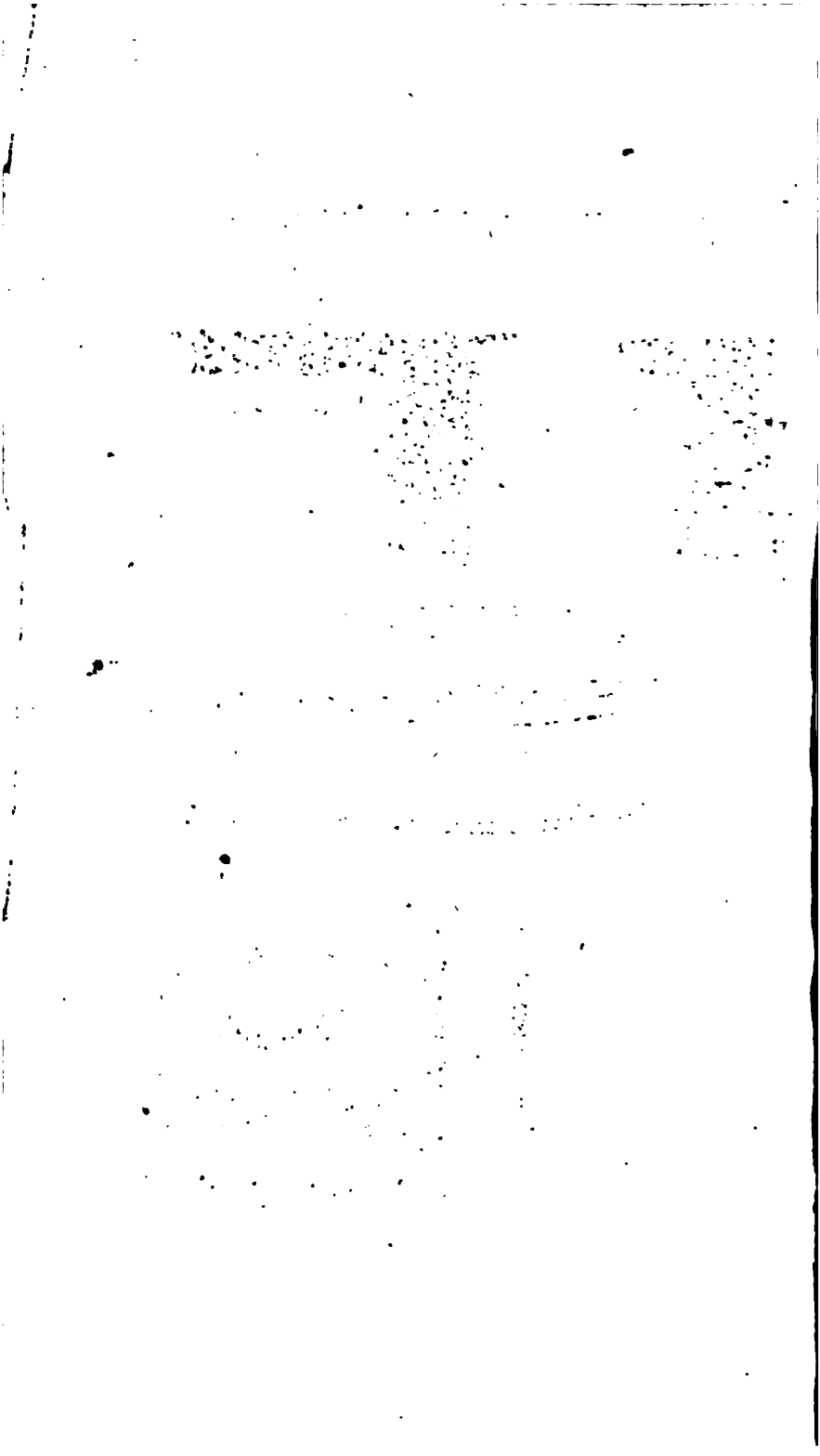

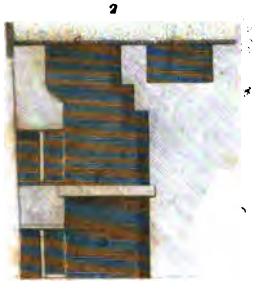
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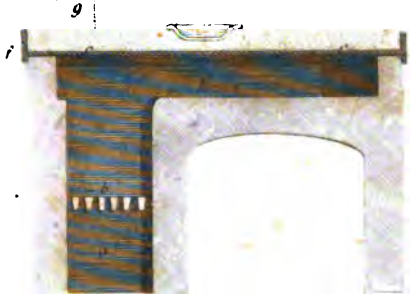
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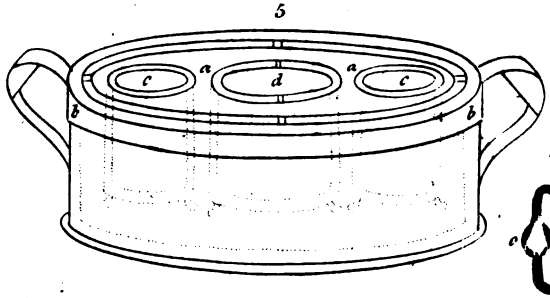
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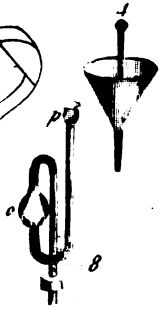
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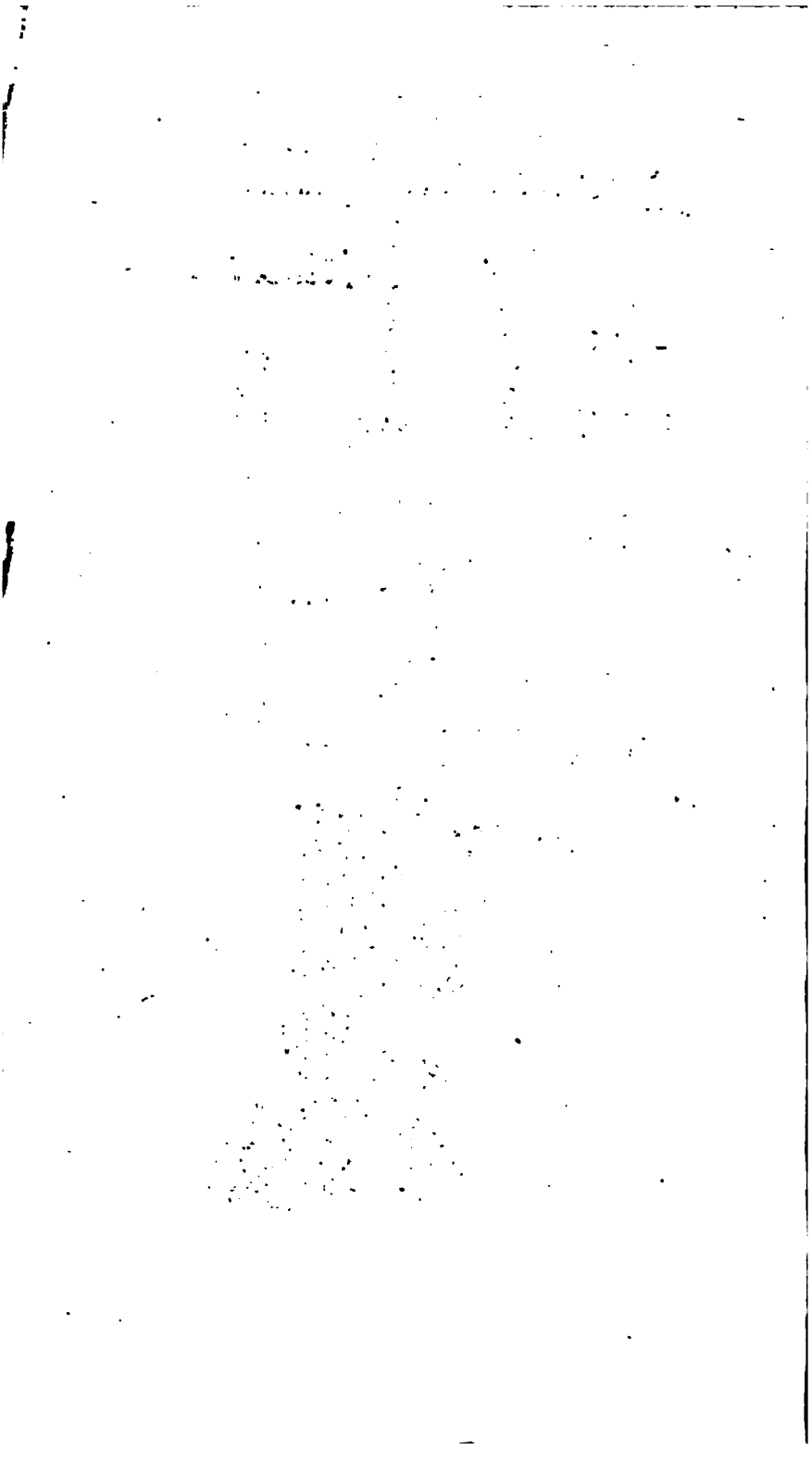

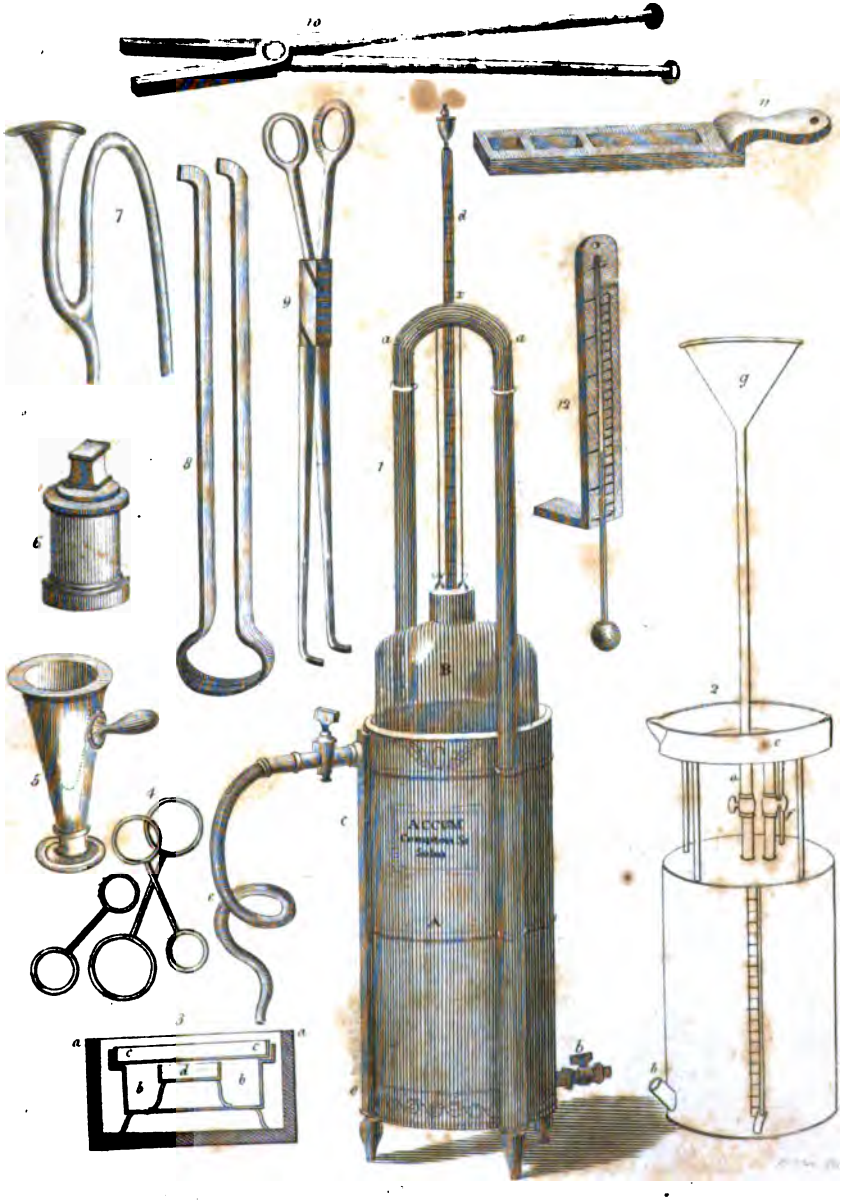
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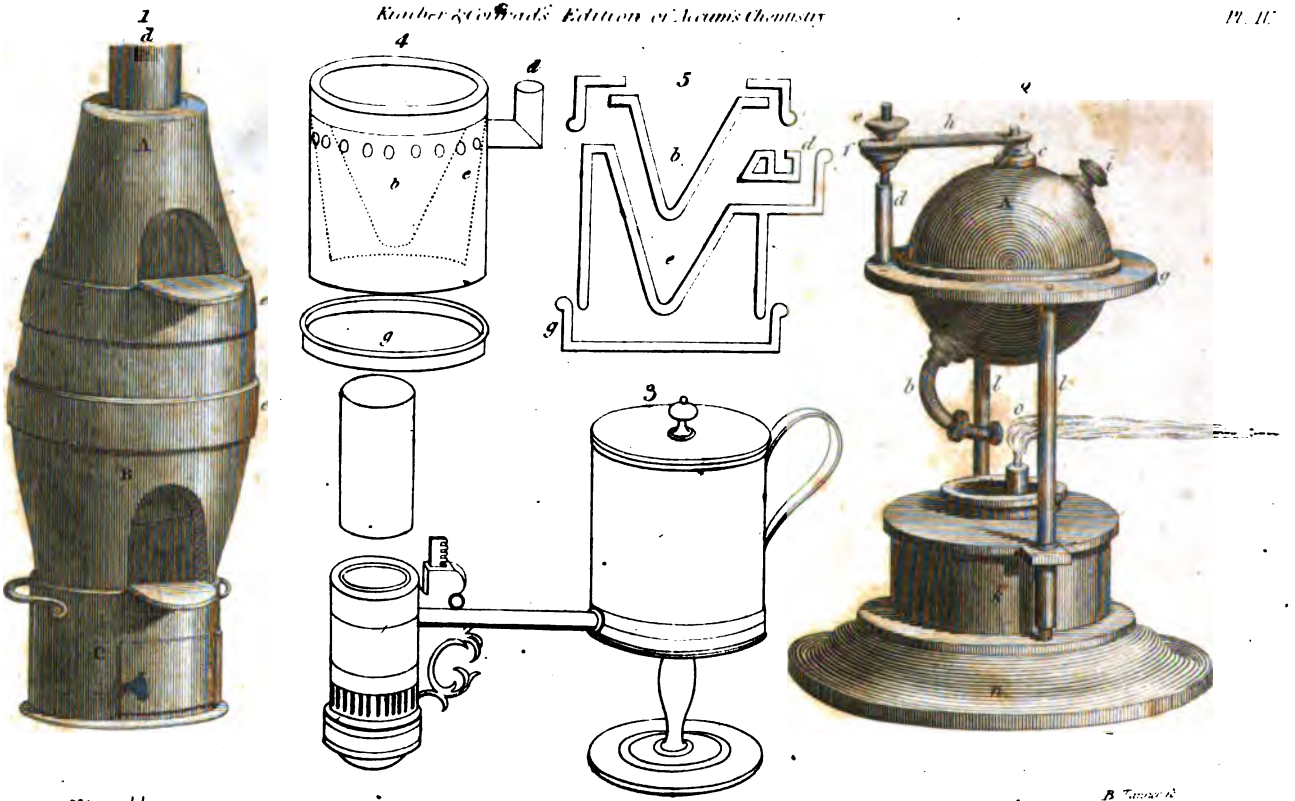

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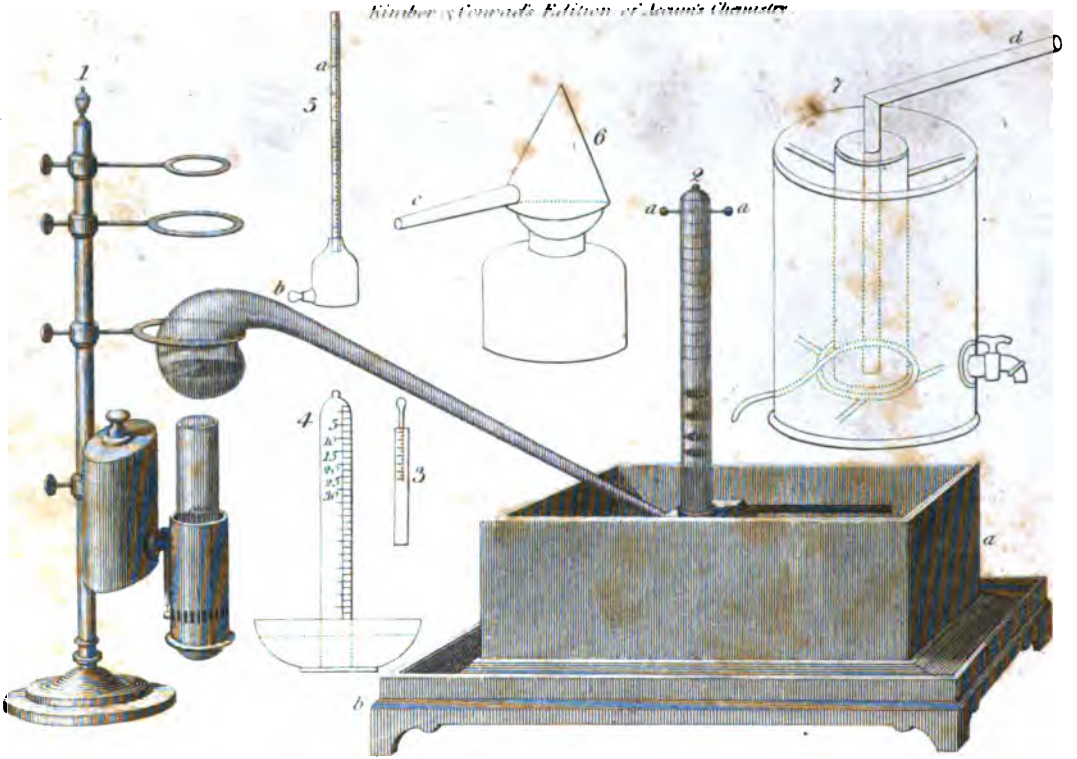
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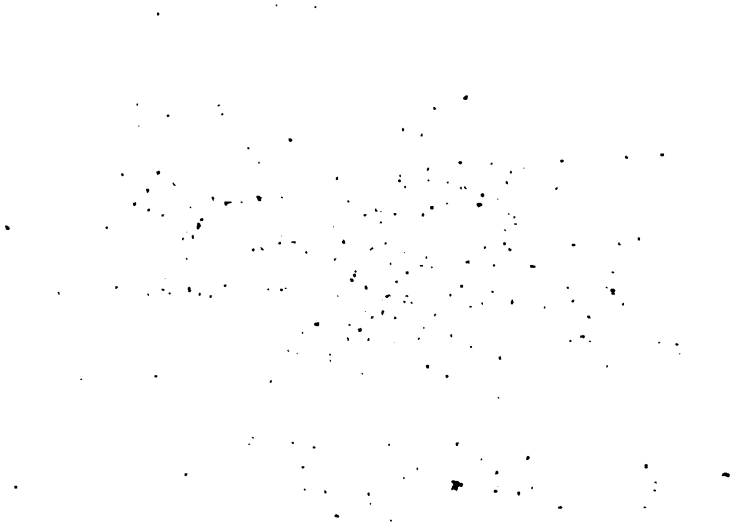

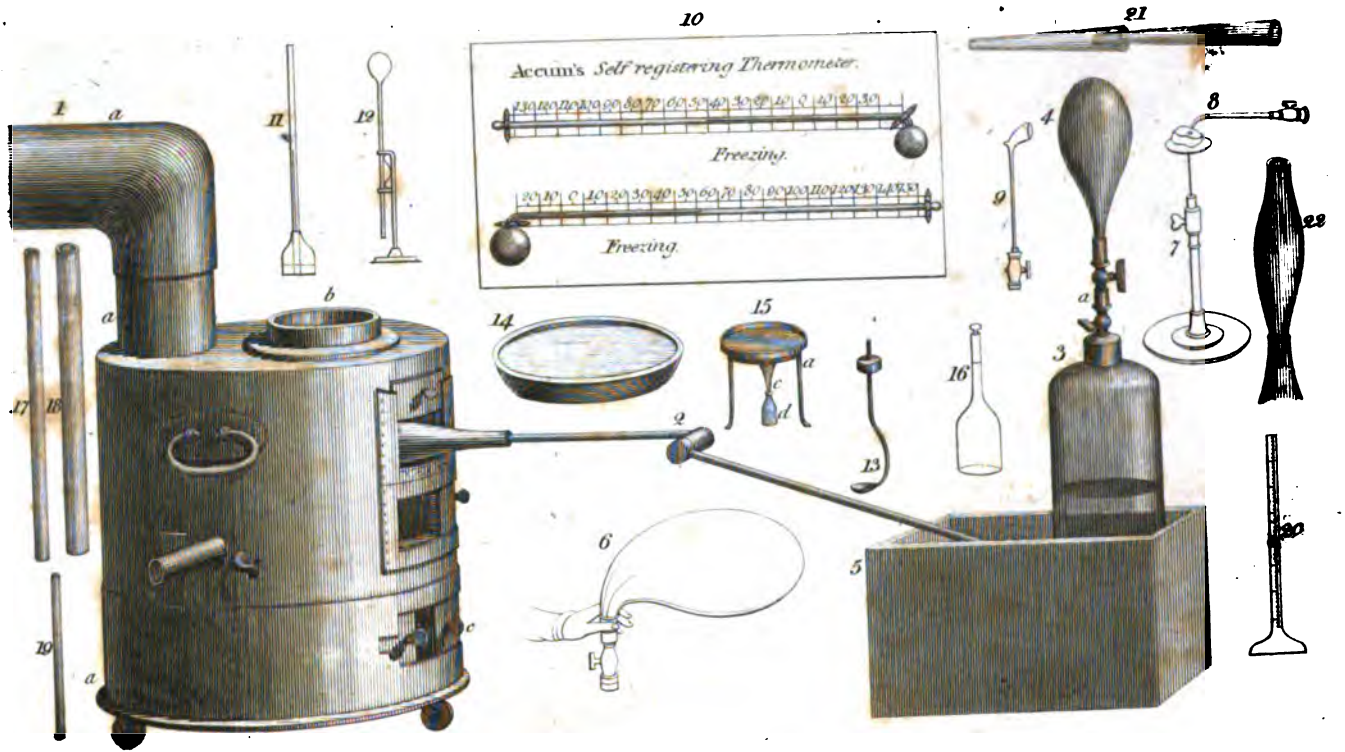
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